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This edition is a continuation of previous publications on the findings related to the geography of infectious diseases. Factual data on the world geographical distribution of melioidosis and onchocerciasis are given. The corresponding geographical distribution of alveococcus and exhaustive factual data on the locations of this parasite within the USSR are also presented. The works are provided with bibliographies. The publication is meant for scientists and field workers, medical geographers, epidemiologists and parasitologists. The nature of the publication is scientific and informatory.

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THE GEOGRAPHY OF MELIOIDOSIS

V.A. Kraminskii and L.E. Naletova

Melioidosis is an infectious tropical disease affecting domestic and wild animals and man. In its acute and chronic forms it causes great distress, high mortality and polymorphism of symptoms. It also has many subclinical and latent forms. Its epidemiology has not been studied to any great extent.

The causative organism of melioidosis was isolated by Whitmore and Krishnaswami [105] in 1911 in Rangoon (Burma). The disease was called 'Glanders-like Rangoon Disease'. Later, it began to be known as melioidosis (which means 'glanders-like') or pseudoglanders [85, 87, 95].

The causative organism of melioidosis is *bacterium whitmori* or the bacillus of pseudoglanders - malleomyces pseudomallei (Breed, 1948). This microbe is also called *Bacillus pseudomallei* (Whitmore, 1913); *B. whitmori* (Stanton and Fletcher, 1921); *Pfeifferella pseudomallei* (Ford, 1927); *Flavobacterium pseudomallei* (Bergey, 1930); *Sclerothrix whitmori* (Vuillemin, 1931); *Actinobaccillus pseudomallei* (Thompson, 1933); *Loefflerella whitmori*, (Breed, 1938); *L. pseudomallei* (Brindle and Cowan, 1951); *Whitmorella pseudomallei* (Brygoo, 1957). As observed by Brygoo [11], the nomenclature and the taxonomic classification of the causative organism of melioidosis cannot be taken as finally settled despite the fact that this organsim was isolated 57 years ago.

The authors who consider the causative organisms of melioidosis to be a species of the *genus Melleomyces* [9] as also a species of the genus *Pfeifferella* [95] combine them into a single genus with the causative organism of glanders. This is justified from the point of view of their antigenic and other properties as well as the similarity of the pathogenic diseases caused by them. The most important difference between these two bacteria and the bacillus of pseudoglanders is the protective cover and mortality of the latter, its considerably pronounced biochemical activity and resistance to the influence of external environmental factors. Legroux [49] and others consider the bacillus of melioidosis as belonging to the genus of blue pus bacillus (*Bacillus pyocyaneus*) (*Pseudomonas aeruginosa*) and as being an intermediate form between the latter and the glanders bacillus; they call it *Pseudomonas pseudomallei* [11, 77]. Some are of the opinion that the *Bacillus whitmori* is actually a mutant of the *Bacillus pyocyaneus* (*Pseudomonas aeruginosa*) [72, 12, etc.].

The causative organism of melioidosis is an anaerobe that does not require a nutritional environment and can grow and reproduce on inorganic matter (Mesotrof). It can exist and reproduce in clear or dirty water for many years. Taking into account these characteristics of the *Bacillus whitmori*, Fournier and Chambon [31] as well as several French and Vietnamese authors conclude that the natural media in which this microbe thrives are water and soil and that melioidosis should be included in those groups of diseases that originate in the external environment. (That is to say saprogenic, from decayed and putrid matter).

Besides man, under normal conditions many domestic animals such as cattle, sheep, goats, pigs, horses, cats and dogs as well as wild animals such as rodents, monkeys, and kangaroos [26, 31, 67, 72, 76, 91, 95, 99] are prone to melioidosis. Laboratory rodents (guinea-pigs, rabbits, albino rats and mice) are affected and are susceptible to experimentally induced infection. In guinea-pigs even apparently spontaneous outbreaks of melioidosis have been recorded.

In man melioidosis usually occurs as a fulminant infection and without treatment with Chloramphenicol and certain other antibiotics mortality is 90% to 95%. In chronic forms mortality is less (about 50%) and the disease can last for many months and even years. The clinical forms of melioidosis vary a great deal. The following are known:

a) Septicemic forms of melioidosis which usually terminate in the death of the patient between the third and tenth day of infection when general toxemia, ataxic and adynamic syndromes and sudden cardiac failure occur. Diagnosis is very difficult because the symptoms usually cannot be diagnosed until after the death of the patient.

b) In the septicopyemic form the disease lasts longer (up to three weeks) and the toxic symptoms are accompanied by pus formation in the lungs and sometimes in the liver, kidneys, urinary bladder, peritoneal cavities, muscles, bones and many other organs. Death occurs as a result of profound cachexia. Diagnosis of the septicopyemic form of melioidosis is very difficult without bacteriological investigations.

c) The localized forms of melioidosis continue as a chronic infection, producing absesses in the subcutaneous tissues, muscles, lymphatic glands and tubular bones.

Melioidosis most often occurs as a latent infection in man as well as in animals and is neither accompanied by the bacillus isolation nor by clinical symptoms. Traumas, surgical interventions, infectious diseases (dysentery, malaria, typhoid, kala-azar, ricketsiosis, syphillis and many others), chronic toxemia, pregnancy, malnutrition, exhaustion, etc. cause the latent infection to become clinically manifested melioidosis.

In regions where melioidosis is endemic a high percentage of the local inhabitants give a positive serological reaction to this infection. This phenomenon is considered by the majority of authors as proof of the infection being present in a latent or subclinical form. Thus in endemic regions melioidosis is much more widespread than officially recorded since many cases would not be registered.

In South-East Asian countries, men whose work involves walking in paddy fields, irrigation canals, mangrove forests and in humid, marshy jungles are particularly prone to melioidosis. These infections are more common at the time of army movements.

Because the incubation period of melioidosis is of uncertain length infection can occur at any time of the year but is more common during the rainy season which is perhaps due to an increase in the number of stagnant pools of water which are likely to be highly contaminated.

The question as to the carrier of melioidosis is still controversial. At first it was presumed that rats were carriers [87]. Their high susceptibility to experimentally induced melioidosis and the finding in 1932 in Malaya of the infection occurring spontaneously in the gray-backed rat (*R. rattus griseiventer*) [94] and in the domestic rat (*R. rattus diardii*) in Indonesia [59] were the basis for this presumption. However, it has not been possible to isolate B. whitmori in rats even though thousands of rats were examined for melioidosis in particular as well as for plague in the regions where melioidosis is endemic [31]. That there is any epidemiological or epizootological correlation between man and domestic animals and the infected rats has never been established [31]. In the light of the presently available data it can at the most be said that only isolated cases of infected rats had anything to do with their contact with diseased domestic animals.

In the fifties the opinion that melioidosis was saprogenic was widely held and was based on three factors: that the causative organisms and bacteria of melioidosis were usually to be found in dirty water and soil; that experiments had shown the ability of B. whitmori to thrive (for some years) and multiply in sterile water (under laboratory conditions) as well as in the dirty water of rivers, canals and ponds; and that this microbe is clearly mesotrofic in nature [13, 29, 31, 48]. At the beginning of the sixties a great deal of data accumulated indicating that domestic animals such as sheep, goats, buffaloes, pigs and sometimes horses are the carriers of melioidosis [31, 60, 61, 72,etc.]. Melioidosis seems to be a typical zoonotic disease in its new locations in Australia and the Antilles Islands as well as in the old locations of Vietnam, Cambodia and others. Autochthonous instances of human melioidosis occur where the disease is enzootic in farm animals who are its carriers and distributors. We therefore think that melioidosis should be included in the zoonotic group (zooanthroponosis) rather than in the saprogenic group.

The way melioidosis spreads has been inadequately researched. It was initially thought that the infection occurred in humans by way of the alimentary tract as a result of their consuming food or water contaminated by the feces of the carrier rodents. At present there is a strong basis for thinking that domestic animals (buffaloes, sheep, goats, pigs, horses) infected with melioidosis contaminate the surrounding environment by expelling the causative organism through sputum (in the case of lung infections), pus from absesses on the skin, nasal mucus and urine. Excretion of the bacillus through feces is rare. Lewis and Olds [51] think that goats can harbor and secrete the causative organism in milk for several months at a time. The causative organism remains alive in the tubular bones of dead or butchered animals which can bring about the infection of pigs that are frequently fed on these bones [31].

That infection of the skin plays the greatest part in the spread of melioidosis should be seriously considered. Many observations made in wartime Vietnam [13, 31] showed that men usually become infected with melioidosis as a result of walking in contaminated pools of water, rice fields or irrigation canals with broken skin (the places where leeches, mosquitoes and other blood suckers have bitten and other open wounds). Infection through the punctures of morphia injections, heroin, etc. is also known. Nevertheless, some authors continue to think that the alimentary tract is one of the main routes of infection [30].

Direct contact between men or between animals or between animals and men plays no significant role in the spread of the disease. There are no data to suggest that melioidosis is an airborne infection. Joubert and Phung Van Dam [40] assert without any tangible proof that melioidosis is transmitted from animals to men through the bites of mosquitoes, ticks, etc. and through rat bites and contaminated food and water.

It has not, however, been possible to study these modes of transmission of the disease under natural conditions. The first assertion is based on Blanc and Baltazard's observations which show that the tic, xenopsylla cheopis, and the mosquito, aedes aegypti, are capable of being infected and can preserve the causative organism of melioidosis for a certain time and transmit it to laboratory animals. It was also thought that there was some relationship between the incidence of melioidosis among the soldiers of the French colonial army at the time of their operations against the people of Vietnam and the attacks on them by blood-sucking anthropodes and leeches. However, it is possible that these blood-suckers were not the actual vectors but by breaking the skin of the soldiers with their bites they indirectly allowed the causative organism to penetrate. That infection occurs as a result of rat bite has never been established.

The ways melioidosis is transmitted and its carrier need to be further researched. However, detailed data collected in the last decade give a definite indication that the infection is transmitted by penetration of the skin of men by the organism, which is present in dirty pools of water, marshy slime, rice fields, irrigation and stagnant canals. The soil and water become contaminated with the organism by the excretion and corpses of infected buffaloes, pigs and other farm animals.

American epidemiologists and bacteriologists who studied the problem of the organisms being picked up in wartime concluded that it could be a prospective agent for use in 'biological warfare' [80].

DISTRIBUTION OF MELIOIDOSIS

Asia

The distribution of melioidosis was initially restricted to the countries of the Indochinese peninsula. After melioidosis was first found in Burma in 1911 [105] a number of other cases were reported there by Whitmore [103, 104] in 1912-1913, by Knap [45] in 1915 and by others. It was noticed that there was high incidence of the disease among morphine addicts and other narcomists taking drugs through injections [31, 44].

In the Federation of Malaya, now part of Malaysia, melioidosis was first detected in 1917 by Stanton [85]. More recently it was found in men as well as in animals (horned cattle, horses, dogs, cats, etc.) [22, 27, 36, 42, 43, 81, 86, 87, 88, 89, 90, 91, 92]. In 1960 a case was recorded of the causative bacillus of melioidosis being isolated in the large intestine of a goat in Malaya [83]. In 1963, Montgomery [58] recorded the case of a soldier who had lived for a long time in Kuala Lumpur dying of melioidosis after landing in Great Britain.

On the basis of data collected from 3,068 post mortems out of which the causative organism of melioidosis was isolated in 14 cases [0.45%], Stanton and Fletcher [91] concluded that there were not more than 200 cases of melioidosis a year in the Federation of Malaya (0.45% calculated on the basis of the overall annual mortality). Later, Field (cited by Fournier and Chambon [31]) came to the same conclusion. In Sabah (North Borneo, now part of Malaysia) melioidosis was first observed in 1963 when there was an epizootic outbreak in pigs [94]. The causative organism was then isolated in 12 out of 411 samples of water taken from open reservoirs.

In Singapore cases of melioidosis in humans were observed by Jilmore [cited from 31], Whitmore isolated a culture of the causative organism of this disease in a monkey in Singapore in 1957 [cited from 31].

Melioidosis was first reported in Vietnam in 1926 [101, 102]. The causative organism was isolated many times in man [28, 29, 31, 45, 50] as well as in buffaloes, pigs and other domestic animals [28, 31, 60, 61, 71, 72, 73] and in the external environment, especially water [14, 29, 31]. The bacteriophage of melioidosis was isolated in stagnant waters around Hanoi [48]. Fournier and Chambon [31] indicate that in domestic animals (goats, pigs, buffaloes) in Vietnam, aglutinations in respect of Whitmori are usually found. These authors feel that though melioidosis in man occurs rather sporadically in Vietnam and particularly in South Vietnam (the old provinces of Annam and Kokhnikhin), it would be a mistake to think that the disease is less widespread. Many cases remain unnoticed because it is so difficult to diagnose (as a rule it can be done only after the patient has died) and because of the fact that farmers who are most exposed to the risk of infection receive very little medical aid and the bodies of their dead are rarely buried, The greatest outbreak of the disease occurred among the French soldiers during the fighting in Vietnam in 1945 and 1954. American soldiers while active in Vietnam also suffered from this disease although the number of registered cases was small. To some extent this is because the disease is often diagnosed as something else (tuberculosis, mycosis,etc.). Another reason for the lower incidence among the American soldiers is the fact that due to helicopter transport they no longer had to walk through marshy land and rice fields. Nevertheless there are reports [24] of seven cases in which the causative organism of melioidosis was isolated and of the disease being carried to the United States by soldiers who had been stationed in South Vietnam [2, 69].

In Cambodia melioidosis was first reported in 1930 by Gambier [32].

Nou Penh reports [64] an outbreak of melioidosis among horses near Phnom Penh in the year 1958. In 1960 there was an epizootic outbreak [30 cases] in pigs with a heavy death toll [64, 100]. The cause of the outbreak was the import of breeding pigs from Australia or from the island of Java (neither region has melioidosis). Nou Penh observes that local breeds of pigs living in contact with the infected, imported animals were, as a rule, either resistant to the disease or suffered from the latent and chronic forms of melioidosis. Nou Penh further notes that Cambodia and other countries of Southeast Asia happen to be a part of the old endemo-enzootic regions of melioidosis. This is confirmed by the fact that domestic animals of the region have a certain resistance to melioidosis though they may often carry *B. whitmori*. It should be noted that unimmunized, imported pigs after mixing with infected pigs of Cambodia produced an outbreak of melioidosis.

In Thailand melioidosis was observed by Paton, Peck and Van de Schaaf in 1947 [68]. Nigg [63], who examined the blood serum of Thais (prior to experimental vaccination against melioidosis) observed that of the 337 sera samples from Thai men, 11 gave a positive and 17 gave a mildly positive reaction to the complement fixation test for melioidosis. Of 78 sera samples from Thai women only one gave a positive reaction to the complement fixation test. When a hemaglutination test was carried out with polysaccharide antigen, 118 sera of the same 405 Thais gave a positive reaction. Of 121 Americans given a hemaglutination test nine gave a positive reaction, eight of whom had served in the United States army posted in countries that were endemic for melioidosis. The author considers that those who had a positive sera reaction carried a subclinical form of melioidosis. As a result the infection has become very widespread in Thailand mostly in a latent, subclinical form, making its detection difficult.

Among the countries of the Indochinese peninsula instances of melioidosis are fewest in Laos. It is however present in that country.

In Indonesia, melioidosis occurs in isolated cases in human beings and animals (horses, rats). In Java it was first observed in the people of Bantama in 1929 [36, 37] and in animals in 1932 [59]. Melioidosis was also observed in human beings in 1938 [96, 82]. In Sulawesi [Celebes] Bezemer in 1935 [4] described the infection of the population by melioidosis. Brockelmann [10] described an outbreak of melioidosis in 1958 near the city of Semarang (Java) which produced symptoms similar to those of cholera. Diagnosis was confirmed by the isolation of the causative organism in the feces. An investigation carried out at the same time on 935 rats caught in the same area because of plague did not give positive results for melioidosis. Because the cases of melioidosis in Java and in Sulawesi were observed in local domestic animals and rodents and also in men who had not gone out of Indonesia or even beyond their own island it can be assumed that the disease there is either autochthonus or was brought there from countries of the Indochinese peninsula a long time ago.

In the Philippine Islands, Cornell [cited from 31] isolated B. whitmori in 1947 in a pony of local breed brought there from Manila where it had been infected and where the first signs of the disease had been confirmed by Gutner and Fischer [35].

In Ceylon melioidosis was observed in 1927 by Denny and Nicholls [23] in a man and in 1930 by Nicholls [62] in a cow.

Melioidosis was reported in 1953 in central India [38].

In southern China, melioidosis was diagnosed by Whitmore (cited by Fournier and Chambon) [31]. Melioidosis was also observed in 1957 in Turkey (in the city of Ankara) where its causative organism was isolated in a man from the pus of an abscess [cited from 31].

Europe

A number of instances of melioidosis being carried to Europe, mainly by army personnel returning from the countries of Southeast Asia, were noted in European countries such as Great Britain [34, 54, 58], France [25, 70, 75] and the Netherlands [31]. Gren'e de Kardenal' in 1952 [cited from 31] reported on seven instances of melioidosis in Berlin at the very end of the war among the hunger-stricken population of Runo. The origin of this outbreak remained untraced.

Africa

In 1936, Girard [33] reported an outbreak of melioidosis in pigs in the island of Madagascar.

Mayer and Finlayson [56] reported cases of melioidosis in South Africa among repatriated soldiers in the year 1960. Provost and Vigier [74] reported the isolation of two strains of the causative organisms of melioidosis in the Republic of Chad. One strain was obtained from a local goat. The other was obtained from a soldier who had returned from Indochina five years earlier. This led to a discussion by the authors as to whether melioidosis in Africa is an autochthonus or a transported infection.

Instances of melioidosis in man and domestic animals have also been registered in Uganda [43].

America

In the United States of America, cases of melioidosis have been registered among the population of Missouri, Colorado, Louisiana and other states. [2, 3, 35, 53, 93]. Some were observed in repatriated soldiers but there have been instances of people who had not been out of the United States being infected. One patient had never left American soil but had lived for two years near the Panama Canal through which pass many passengers from Southeast Asia.

In the Lesser Antilles Islands, Sutmoller, Krapeveld and A. Van der Schaal [98] working on the island of Aruba noticed rather frequent occurrences of abscesses of the lymphatic glands of sheep, goats and pigs at slaughter time. They made cultures from the pus and isolated *Bacillus whitmori*. Further investigations on Aruba revealed epizootic melioidosis among the local cattle. For example from one flock of 90 sheep, 25 were found to be infected with the disease. It is thought that the sudden epizootic outbreak in the Lesser Antilles Islands, the speed with which it spread and the high incidence of melioidosis revealed in the post-mortem examinations indicate that the disease had recently been transported to the islands [31, 98].

There are reports of the infection of man by melioidosis in Ecuador.

Australia and the Pacific Islands

Cox and Arbogast [20], Mirik *et al* [57] reported instances of melioidosis on the island of Guam transported from Southeast Asia after the

Second World War.

In Australia, melioidosis has been observed since 1949. Initially it was found in the north of Queensland, i.e. in the tropical zone. Cottew [16, 17], Autherland and Meehan [18, 19], Lewis and Olds [51], Crotty, Bromwoca and Quinn [21] and others [65, 66, 67, 76, 77, 97] reported widespread epizootic as well as isolated infections of sheep, goats, pigs and horses. Laws [46, 47] isolated strains of *Bacillus whitmori* in north Queensland between 1956 and 1961 in 116 animals. The majority of the strains were isolated in the pus of abscesses found during postmortem examinations of the carcasses. Only 12 animals showed clinical symptoms. In the zoological garden of the city of Townsville which is in the center of the area infected by melioidosis, an orang-outang that had been imported from the island of Borneo four years earlier died from the disease [99]. Instances of men being infected with and dying from melioidosis in Australia have been reported by Mac Kerr [cited from 31]; Rimington [78] who recorded six cases of melioidosis in Queensland in 1950, one in 1959 and one in 1960; Crotty, Bromwich and Quinn [21]; Johnson [39] who reported four cases of melioidosis among the inhabitants of the small island in the Torres Straits to the north of Cape York, and a number of others [41].

Fournier and Chambon [31] consider that melioidosis was brought into Australia with cattle at the end of the Second World War or just after. Though Australia is an exporter of cattle, she imports a very few animals for breeding purposes. Discussing the recent incidence of melioidosis in Australia, Fournier and Chambon [31] and a number of other Australian authors point out that detailed and regular examinations of cattle, at the time of slaughter particularly, did not reveal a single case of melioidosis until 1949. This shows how quickly melioidosis has spread, leading to large-scale epizootic outbreaks after 1949 with considerable mortality. Cook [15] in 1962 serologically examined rats (*R. rattus*, *R. assimilis*, *R. norvegicus*) and kangaroos (*wallabia ruforgrisea*, *macropis major*, *megoleia rufa*) from northwestern and southeastern Queensland. Positive results (in dilutions of 1:10 and 1:20) were obtained in three out of 56 kangaroos and in 29 out of 272 rats. In one rat the agglutination reaction was positive at a dilution of 1:40 and in two it was positive at 1:80. From the examination of many other rodents, marsupials, birds, amphibia, lizards and snakes, negative results were obtained. The author also examined blood sera samples of 619 men from regions not entirely free from melioidosis. Except for the sera samples of patients suffering from melioidosis, from which a culture was separated, all the remaining sera samples gave negative results. So in the regions which are enzootic for melioidosis in Australia the disease only rarely affects human beings. This could have some relation to the absence of humid, tropical forests, marshy fields, etc. which promote the infection of man by melioidosis.

In Papua (New Guinea) a leper who for two years had been in a leper colony on the island near Port Moresby [79] became infected. Earlier in Papua [26] a culture of *Bacillus whitmori* had been isolated in a three-year-old kangaroo.

Generally speaking, the areas where melioidosis is present can be divided into three separate regions:

1) The old endemo-enzootic areas where the disease has long existed and is autochthonous: Vietnam, Malaysia, Cambodia, Burma and Thailand. In this region melioidosis occurs mainly sporadically, affecting both the local human population and farm animals of local breeds. A large number of subclinical and undiagnosed cases of melioidosis are not registered. The surrounding environment, especially ponds, springs, paddy fields, bogs and the soil, is usually contaminated with the causative organism. According to registered data, visitors to the region are more susceptible to infection than the local inhabitants. However, 7% to 8% of the local population give a positive serological reaction to melioidosis. Large epizootic outbreaks leading to high mortality are likely to break out among imported cattle. The local breeds usually suffer from either a chronic or a latent form of the disease.
2) The new endemo-enzootic areas to which melioidosis has recently been transported, where the causative organism has found a permanent habitat among domestic animals. Large outbreaks with high mortality and sporadic occurrence of the disease among men (North Australia, Aruba Island) are included in this region.
3) Regions where the disease has been accidentally carried, leading to isolated cases of humans and animals being infected but where it does not take root. For example, the Phillipines, Indonesia, Singapore, India, Ceylon, China, Turkey and the countries of Europe, Africa and North America.

To date all the endemo-enzootic areas of melioidosis, whether of early or recent origin, which become such as a result of its being imported by cattle, are in the tropics. Although it has also been carried to other areas having a temperate climate it seems that it can only take root in tropical or subtropical climates. Nevertheless, the possibility of the causative organism becoming acclimatized or taking root even in countries with a temperate climate should not be ruled out as the *Bacillus whitmori* is very changeable and has a strong resistance to the outside atmosphere.

From this point of view, it is very necessary that all farm animals, particularly goats, sheep and pigs imported into the USSR from countries where melioidosis is present (Southeast Asia, Australia, Lesser Antilles) should be strictly subjected to seralogical examinations and skin sensitivity tests for melioidosis. Should post-mortem examinations of carcasses reveal absesses of the internal organs, the pus from these should be cultured in a special medium to determine whether melioidosis was the cause.

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LANDSCAPE AND GEOGRAPHICAL REGULARITIES OF DISTRIBUTION OF ALVEOCOCCUS, PART I - USSR

B.V. Vershinskii

INTRODUCTION

Alveococcus (alveolar or multilocular echinococcus) is one of the most serious diseases caused in man by an animal parasite. The direct cause of the disease is the infection of the internal organs by the cystode alveococcus multilocularis in the larval stages (Leuchart, 1863); (Abuladze, 1959). The parasitic tumor that appears is characterized by a continuous, infiltrating growth and is capable of producing metastasis reminiscent of a malignant tumor and in fact, as with a malignant tumor, unless a timely operation is performed death results. Diagnosis of alveococcus while the patient is still alive is rather difficult at the ordinary clinic. According to the data of A.F. Protasovaya [363], of 29 patients who had died from alveococcus, only six had been correctly diagnosed while living. Similar findings have been recorded by other authors [74, 278, 364, etc.]. Recently some progress has been made in the diagnosis of alveococcus due to the development of laboratory techniques by which the infection can be detected in man. From complex research being carried out among the populations of regions where the helminth proliferates doctors are gaining more and more knowledge of alveococcus.

The research is likely to yield more concrete results, both from the curative and from the prophylactic point of view, if it is based on a knowledge of the territorial distribution of alveococcus. This demands a rather complete knowledge not only of the comparative incidence of alveococcus in the different regions of the USSR but also of the factors determining the level of the infection and the degree of potential danger to the natural environment from the initial disease-carrying agent. Like other diseases that originate from the natural environment, alveococcus presents the phenomenon of being organically connected with the peculiarities of the landscape (its geographical and hydrological characteristics, the distribution and composition of vegetation, groupings of animals, etc.) and on how the inhabited territory is utilized, because in these situations man is exposed to the danger of infection.

Evaluation of the 'carrying capacity' of the landscape in respect of alveococcus and the spread of the disease among the population being dependent on these factors are problems of foremost importance. As the problem stands at present, it can only be solved on a national scale by processing the vast amount of information available from a geographical standpoint.

By this is meant that first and foremost special methods of cartography combined with detailed mapping of the geographical surroundings should be followed for such studies. Only from a combined cartographical analysis of medical and geographical data is it possible to find the territorial distribution of the disease as well as to have an idea of the significance of the spaces between the affected pockets and the cause and effect relationship. In other words, the very process of preparation of maps on the basis of the content of other cartographical data and the data in literature represents an independent method of investigation. Its research prospects and potential have been partly described by K.A.

Salishev [375]. This does not preclude the use of the cartographical approach. Its importance as a method is not disputed. In order to work out the composition of the map only such data need be considered as are very closely connected with the geographically significant factors. Many works have not paid much attention to this elementary requirement. It follows that in order to make the best use of the information available ways and means of putting the data together have to be found.

As far as the presence of alveococcus in this country is concerned this is very necessary because research has been and is being carried out without any standard method being followed. This has led to a great deal of different data being collected in different forms that are of little use as a whole. What is needed is for the data that is collected to present a composite picture in which each piece of information has a significant place, however small. Nevertheless, of the total number of reports we have considered (almost 450), about 150 proved directly useful for cartographic purposes. These have been mentioned in the bibliography and a comprehensive picture has been given in the cadastral data on alveococcus in animals and man in the USSR (see annexure).

Data on the incidence of alveococcus in man and animals have been given along with cartographic and descriptive data of the environments in which they live, the distribution of the landscape and the ecology of the animals [267, 268, 274, 280, 288, 302, 303, 304, 326, 331, 346, 365, 382, 393, 394, 397, 398, 399 and others]. This made it possible to present the map included in this work and to examine the regional peculiarities of alveococcus in the USSR. No particular attempt has been made in literature on the subject to examine the structure of the regions where this disease has spread, taking into consideration the various effects landscape and geographical factors have on alveococcus.

This gap has not been filled by the data collected over the last few years, most of which is confined to particular aspects of the study of alveococcus [95, 134, 262, 277, 283]. The latest paper written from a geographical angle is by A.D. Lebedeva and M.A. Savinoi [333]. It was published in the book of *Itogi nauki* though the global character of the summary and the need to examine the literature on unilocular echinococcus at the same time did not permit the authors to examine fully the structure of regional distribution of alveococcus within the USSR. Before we begin, mention should be made of a small research paper by N.P. Lukashenko [335]. Unfortunately the ideas expressed in this paper were not followed up in the author's subsequent work. The basic features of the distribution of alveococcus in the USSR were mentioned in the geographical map *Diseases with a Natural Habitat* [281]. However, because of the complex nature of this map, alveococcus has been included as only one of the elements of territorial diseases and as a result the details could not be shown. This has been taken care of by the publication of the map in the present work. (The original map was prepared by V.K. Simonovich of the Institute of Geography in Siberia and the Far East (SO AN SSSR) at my request. The original was edited at the Institute of Scientific Information, Academy of Sciences, USSR). The data presented in this map shows the correlation between the distribution of the parasite and the regional nature of the landscapes.

As is known, the cycle of development of alveococcus includes parasitization in the bodies of the definitive and intermediate hosts. The definitive host of this helminth is the dog family (polar foxes, foxes, korsaks, dogs, wolves) in which the sexually mature alveococci are concentrated in the middle and lower portions of the small intestine. The density of infection of these animals can be very high (70% to 100%) when the attack is acute and it is sometimes difficult to count the number of parasites. Nearly 25 species of animals have been registered as being intermediate hosts of the parasite, belonging to different families of rodentia (mainly mouse-like animals, beavers, coypu and others). Rodents pick up the infection from the external environment (foliage and berries of shrubs, water, etc.) which have been contaminated by the eggs of the parasite excreted in large numbers in the feces of the canines. The intermediate host is infected even when the eggs have been exposed to the environment for quite some time. This is a very important factor in the epizootology of this helminth to which K.I. Skryabin [381] has drawn attention for the first time. As we will see later, this particular factor has a direct bearing on the degree of carrying capacity of the landscape in respect of alveococcus. The larval stage of development of the parasite takes place in the internal organs of rodents and the cystic swelling increases in size so quickly that in a few weeks it hinders the movement of the host, making it easy prey for wild animals [366]. The canine becomes infected by feeding on the infected rodent. The density of infection in rodents is on the average 3% to 5%. In different landscapes, however, it is highly variable (from 0.01% to 20% or more). There are many reports of domestic ungulates becoming infected at the larval stage [14, 22, 36, 40, 42, 84, 102, 328, 356, 370, 386, 410, etc._7 by the causative organism in those regions of the country for which data on infected canines and rodents is not available. The infected ungulates can only serve as indicators because they do not play any epizootological role in the spread of alveococcus.

The scheme of cycle of development is abstract in those aspects which have been established between alveococcus and concrete species of host, thus forming a significant parasitic system in the natural biocenose. It should be remembered that the system of parasitization is made up of the populations of parasites and the populations of animals which support these parasites and happen to be their hosts and carriers [273]. A population as currently defined in modern ecology is the grouping of animals of one species in a given territory which is their natural ecological environment [353]. In applying the concept of the parasitic system to the ecology of alveococcus it can be seen that its biocenotic relations in general are characterized by a three-tiered parasitic system in which each of the hosts belongs to a particular species, closely resembling each other taxonomically and ecologically, being equally significant in the life of the parasite and connected with each other in the various landscapes. Only the parasite itself is an unchanged connecting factor of the parasitic system in each case. Together with definite landscape-geographical conditions there are some typical variations in the parasitic system in which the species composition of the members (definitive and intermediate hosts) differ both in the level and dynamics of their numbers and in their infecting potential as well as in their epizootological and endemological significance.

NATURAL LOCATIONS OF ALVEOCOCCUS

Tundra and Forest Tundra: Dogs and lemmings make up the parasitic system of this region. It can be presumed that the dog and the narrow-skulled field vole play a considerable role in this though exact data on this particular aspect is not available. M.M. Mamedova reports dogs being infected with alveococcus in the Turukhansk region. In the tundra and forest tundra a larger percentage of canines are infected [60, 66, 71, 76, 87, 113, 118, 124, 295, 377, 402] than in other natural zones where the extent and intensity of infection of wild canines is seasonal. In the tundra and forest tundra regions, large numbers of canines carry the infection the year around. According to A.D. Luzhkova [66] the number of infected canines in Yamal in the tundra is very high (58% to 95%) from May to November. Since the author reports even on young canines carrying the infection in August it can be said with a degree of certainty (data on canines being infected in July are not available) that these wild animals are infected throughout the year. This presumption is based on the biological peculiarities of the lemming. Due to their capacity to reproduce even under snow [303, 326, 401] they provide a "good harvest" for the canines in the following year, giving them good feeding conditions at the time of mating, birth and suckling of their young [304, 365]. The years when large numbers of canines are born are characterized by a rise in the level of alveococcus and intensive oviposition of the external environment, which in turn becomes a basis for the successive infection of rodents by the disease. This unbroken epizootic process is due to the considerable resistance of the eggs of alveococcus to the effects of cooling and increased humidity. It has been determined by special research [68] that during adverse temperatures in field or laboratory conditions the eggs of the parasite preserve their capacity to infect for as long as two or three years. On the other hand drying, particularly direct drying, has an ovicidal effect.*

Lemmings become infected with alveococcus because of their adaptability to a humid habitat where they are always foraging for food (vegetative parts and roots of sedge (Carex), cotton-grass (Eriophorum), etc.). This is particularly abundant and easily obtainable for the polar fox. One place of contact between these species is the small fruit orchards which both the polar foxes and the rodents frequently visit. Though the polar fox risks his life by searching for food in the humidity of the tundra with its low soil and water temperatures his frequent visits facilitate extensive oviposition of the eggs of alveococcus where they preserve their infecting ability for long periods. This combination of factors explains why large numbers of lemmings are infected with the larval stage of alveococcus. According to N.M. Gubaneva's data [295], which concerns the tundra regions of Yakutsk, larval alveococcus was found in 21% of 174 lemmings examined. From the map it can be seen that data on the frequency of larval alveococcus in rodents in the rest of the tundra and forest tundra are not available although there are reports of wild animals being found infected in Yamal, northern Ural'skiy and northern Obskaya Guba [93, 326, 359].

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*Basically similar results were obtained from studies of the resistance of eggs of other genera of the family taeniidae [263, 357, 369, 405 and others]. However, the dependence of the embryonal stages of development on external interactions does not appear to be a significant factor in the formation of noso areas in view of other primary characteristics of the parasitic system and the result of its evolution under the influence of human economic activity.

Further observations on the infecting ability of the dominant species of rodent are no doubt valuable for detailed epizootological and epidemiological evaluation of the landscape for the presence of alveococcus in this natural zone. Of particular interest are the results obtained from observations on the infection of wild canines by alveococcus in the context of population changes and infection of the intermediate host. In this way it would be possible to obtain data which would be extremely important from a scientific and practical point of view. First and foremost, they would give an idea of the seasonal mode of infection of the host and, as a result, of the stability of the epizootological process in given landscape conditions. The last point is very important for evaluating the risk of infection the human population is exposed to and for working out prophylactic measures. It is no less important to find out what the fluctuations of infection are of the definitive and intermediate hosts for some years in order to gauge the cyclical changes in their numbers. It must be mentioned here that data on the infection of alveococcus in canines of tundra and forest tundra zones is not available. Nevertheless, there is some basis for believing that these animals are important members of the parasitic system in a number of regions of the north and northeast of the country. The large number of productive dogs and those used as pack animals together with certain local aspects of their ecology is no doubt significant. For example, during summer mature young animals lead a fairly wild life, depending on mice for food rather than getting the fishmeal supplied by man in winter /398, 404/. Having had such close contact with nature, the dogs come into contact with man in his daily life; thus all the conditions are there for infection with alveococcus while they are feeding on infected rodents and for extensive dissemination of the eggs of the parasite around human habitations. It follows that this is one of the most important factors determining the very high incidence of alveococcal infection among the people of Yakutsk, Chukotsky and Kamchatka, as will be seen later.

It may be mentioned in passing that in the literature of the USSR there are practically no scientific works on the ecology of canines in the various natural regions of the country. Yet their way of life, food, contacts with the natural biocenose on the one hand and with man on the other differ sharply from region to region. This naturally would not be of the same epizootological and epidemiological significance. This is amply demonstrated by the example of alveococcus, data on which we will be examining. The need to look into the comparative ecology of the canine population, laying stress on its epizootological and epidemiological significance, should be emphasized.

Summarizing, it can be said that the tundra and forest tundra should be considered territories having a high risk of infection by alveococcus. The basic reason for this is the wide extent and comparatively steady rate of infection among the polar foxes whose density is very high throughout the tundra with the exception of the Kolymskii peninsula and the islands of the Arctic Ocean. Extremely important are the excessive humidity and low temperature of these types of landscapes, which prolong the infective ability of the eggs of this parasite. Man can be infected in the course of his exploitation of the polar foxes for their products and also through the eggs which have been disseminated on the surrounding environment (berries and water of the lakes in the tundra, etc.). The many dogs which disseminate the eggs of the parasite close to human habitations in this region represent a no less important factor.

Taiga: The coniferous landscape of taiga in general is characterized by almost total absence of the natural habitats of alveococcus because the number of definitive hosts of the parasite (primarily polar foxes) is very small. This is mainly due to the difficulty they have in obtaining mouse-like rodents (which are the staple food of the polar fox) in the taiga forests due to their density and deep snow. However, some taiga regions are an exception. These are regions in which intrazonal types of habitats are widespread (lower reaches of the Obi, central Yakutsk, the north taiga fields with less snow in the mid-reaches of the Yana and Kolyma, and also the hilly areas on the Okhotsk shore, south Chukotskii and Kamchatka where there is a preponderance of cedar forests). As against the rest of the taiga territory, in these areas the number of polar foxes is about the same as it is in the forest steppes [274, 393]. In central Yakutsk and Kamchatka infected polar foxes form as much as 33% of the total [59, 113]. It should be noted that in central Yakutsk there is also a high incidence of alveococcal infection among the dogs, as much as 50% to 80% [113, 377]. There is accordingly an extremely wide distribution of larval alveococcus among the rodents. The infection among the narrow-skulled voles with the larval stage of the parasite being 23% to 70% [113, 295]. This very high level of infection of the intermediate host has a great bearing on the evaluation of the 'carrying capacity' of landscapes. Not only does it confirm the high concentration of eggs of the parasite under natural conditions (this is clear from the incidence of the definitive host). It also sheds light on the great adaptability to the surrounding environment, which provides protection to the eggs when they are oviposited from the body of the host. These facts can be explained by the peculiarities of the landscape of central Yakutsk with its constantly frozen springs and many waterlogged meadows near the lakes, thickly populated with gray field voles. These are also found in large numbers in the homes of the people of this area and fall easy prey to dogs which are reared for their hides and for hunting. Sometimes there are as many as 10 dogs in one household [112]. Besides the gray field voles (narrow-skulled economica) in Yakutsk, Sakhalin and other Pacific islands, other species of rodents such as the red and gray-red field voles and squirrels [113, 269, 295, 350, 377] have also been registered as being intermediate hosts. The infection of the squirrel is of very little epizootological significance but the indicative role of this fact is quite clear.

Apart from the taiga territory, which is surrounded by unspoiled landscapes, other regions where the original landscape has been altered to a greater or lesser extent by the lumber industry and agriculture should also be considered. It is known that this process is accompanied by a sharp rise in the number of polar foxes [336] and accordingly new parasitic systems are created in the animal population of the forest landscapes. This is confirmed by a few reports of the presence of alveococcus in polar foxes, rodents and domestic animals in regions which have recently been brought under the plow in the south taiga and European forests of Belorussia necher-nozemno center, central Povolzhya and central Siberia [104, 312, 344, 367]. Incidentally, these are the regions where alveococcus was first found in man and reported at the turn of the century [307, 341, 342, 347]. The last few years have seen a high incidence of alveococcus in the widely reclaimed taiga region near the Urals though the causative organism has not yet been found in the foxes and rodents of this area [363].

From the data available, however little, it can be concluded that the parasitization system is varied in taiga-type landscapes. Apart from the animals that have adapted to life in the forest (foxes, gray field voles, field mice), other typical forest and taiga species (squirrels, and red-fray field voles) also have a role. It can be seen from the map, firstly, that data on alveococcal infection are available where the number of polar foxes is large though it may not be true of the whole taiga; secondly, that in the places where infected polar foxes were found no research has yet been carried out on the rodents and finally, as has already been mentioned, that the relatively simple method of obtaining material has a great indicative significance for evaluation of a territory in respect of the risk of alveococcal infection.

So as against tundra landscapes, in the taiga and sub-taiga there are sharp local differences in the density of alveococcal infection. The territories with the highest risk of infection have an intra-zonal and extra-zonal character of natural, anthropological origin with which the number of basic endemically dangerous species of polar foxes is related. The role played by domestic dogs is also considerable. Their number and ecology is determined by the particular way of life of the farming population. Of the natural regions of the taiga where the risk of infection has been confirmed helminthologically or epidemiologically mention must first be made of the south taiga regions of Preduralya, the central taiga region of central Yakutsk, the north taiga region, the middle reaches of the Yana and Kolymy, the regions bordering the Pacific Ocean, Kamchatka and the sub-Arctic islands. A high and medium degree of risk of infection is present in a number of taiga and sub-taiga regions where, depending on which type, the natural conditions produce a high population density of foxes. The main body of the taiga and the hilly taiga territories can be evaluated as having a very low incidence of alveococcus.

Steppes and Forest Steppes: The parasitic system is characterized here by the dominant role played by foxes, whose numbers are high throughout the region from Karpat to Zabaikal. It can be seen from the map that the largest number of foxes infected with alveococcus inhabit the region of the forest steppes, steppes and hilly steppes of the Asian part of the USSR [23, 64, 67, 102, 104, 284, 315, 316, 317, 320, 325, 338, 374, 391, 392]. In the European part of the country only Kruym and Dagestan have been covered by research [314, 354, 355, 410] in spite of the fact that alveococcus is present in the forest steppes and steppes south of the Great Russian Plain, near the Volga and Ural. This is substantiated by occasional finds of the parasite in the larval stage in the farm animals and people of these regions. So far the little research on the wild and domestic canines of these regions has yielded negative results.

Compared to their role in the tundra and taiga, the role of dogs in the forest steppes and steppes is less; whereas it has been found from most surveys carried out in the various areas that the percentage of foxes infected ranges from 20% to 40% and at places even from 70% to 90%, the dogs infected nowhere exceed 3% [14, 23, 64, 67, 97, 316, 325, 355, 409, 410, 411]. In some regions the Korsak [382] and the wolf [67, 316] have some significance in this respect.

In the forest steppes and steppes the number of foxes is very closely related to the number of field-voles, first among them being the economica, the narrow-skulled vole, the harvest vole and the common vole. These animals are the staple food of the fox, they are less mobile than mice and are the regular prey of the fox even when their numbers decrease. When this happens the foxes have to cover great distances to seek them out, resulting in a wider dissemination of the eggs of the parasite. Exact data on the number of field voles foxes eat are not available but the fact that the stomach of this carnivore can contain up to 20 such field voles [399] speaks for itself. The gastro-intestinal tract of the fox (which is like that of dogs) plays the role of a typical filter by which process the parasites are separated from the dead rodents in the form of a large biomass. This explains the sharp difference between the very high incidence of the infection of foxes by mature cystodes and the lower incidence of larval alveococcus in the small rodents. In the latter this is on average 3% to 5% though in different regions it can vary from a fraction of one per cent to 10% [64, 67, 316, 339, 391, 395].

Whereas the infection of dogs by alveococcus is more or less constant, the infection of foxes varies with the seasons. The maximum extent and intensity of infection, according to the data obtained from surveys of foxes in the south of Siberia [67, 72, 104, 391], comes at the end of the fall, lessening toward spring and becoming almost non-existent in the summer months. This tendency can most probably be explained by the seasonal variations in the numbers of mouse-like rodents, foremost among which are the grass-eating field voles. As we know, the number of field voles reaches its maximum in the second half of summer toward the beginning of the fall. The maximum number of these wild animals in the steppes is generally related to two adverse forms of microtopography and mesotopography where greater humidity produces a dense growth of grass. These are ideal conditions for the preservation of the life and infecting potential of the eggs of alveococcus. The climatic conditions of the forest steppes and especially of the steppes, where the intensity of sunshine sharply reduces humidity, have a significant bearing on the natural biocenose. In the steppes the distribution of habitats where an active epizootic process can be maintained acquires an isolated character.

To what extent we can judge from the available data including studies of rodents [61, 63, 64, 285, 315, 316, 335, 339, 395, 410] the increasing dryness of the steppes worsens the living conditions of alveococcus even when the number of definitive and intermediate hosts increases. This tendency is clearly demonstrated in the data on the infection of canines and rodents in arid regions (see below). Accordingly, the importance of the intra-zonal areas (waterlogged meadows near lakes, tributaries of rivers) increases where the large amount of moisture in the soil and the increase in the number of rodents helps to strengthen the epizootic process. In this connection the role of the musk rat must be mentioned. The infection of the musk rat by larval alveococcus has been reported in many regions of southwestern Siberia and northern Kazakhstan [64, 67, 315, 317, 332, 374, 388, 396] and also in the meadows, water pools and habitations near lakes and river tributaries of the arid zones [8, 287, 332]. This rodent with its high capacity to retain alveococcus differs from all other field voles in that it has a longer life-span and is always found in large numbers. Because of these characteristics the musk rat plays a significant role in the epizootology of alveococcus, being, as it were, a reservoir for the causative organisms in the years when the numbers of mouse-like animals are low. In many of the forest steppes, steppes and desert regions of the USSR the musk rat is the prey of foxes and wolves; musk rats are often fed to dogs and animals in captivity (polar foxes, silver-gray foxes and others) and usually the liver is purposely left in the carcass; it is in the liver that the larvae of alveococcus grow in large numbers. Thus the musk rat gives a boost to the parasitizing system and facilitates the epizootological process. This poses a danger to wildlife farms where the infection is likely to be introduced and a health hazard for the people working on them.

Although surveys of the forest steppes as a natural location of alveococcus are as yet incomplete it can be said that the climatic conditions necessary for the existence of this parasite depend not only on the latitude of a particular place but also on the provincial characteristics of each zone. Where the moisture levels are relatively low the differentiating effect of zonal factors (relief and hydrography, etc.) is greater than that of the humidity of the air and moisture in the soil on the nature of the biocenoses, the preservation of the infecting potential of the eggs and the influence of the external environment. Other things being equal, the possibility of the parasite surviving in large numbers depends on how mosaic the landscape is, i.e. how complex its structure and how numerous its natural boundaries where an active epizootic process could go on. From this point of view the forest steppes have perhaps more possibilities than the steppes. In their turn, the forest steppes of western Siberia and northern Kazakhstan with their large numbers of lakes, waterlogged meadows and many divisions in agricultural holdings are not at all like the forest steppes of the Great Russian Plain which is very well drained and has been more uniformly cultivated. In the same way, the cultivated lands could be compared with the European steppes, the steppes of western Siberia and the hill steppes of Kazakhstan. The regional differences between the parasitic systems of alveococcus are most certainly governed by anthropogenical factors as well. It is known, for example, that the plowing of the virgin steppes of western Siberia and northern Kazakhstan led to a considerable change in the animal population of these parts; the number of polar foxes sharply increased while the number of korsaks and suroks decreased; there was also a change in the ratio of grass-eating and grain-eating rodents /321, 322, 382, etc./. How does this change in the numbers of these animals affect the parasitic system of alveococcus? Does the intensity of the epizootic process increase because of the increase in the number of polar foxes or because of the sudden change in the rodent ratio? Does the risk of infection to the human population increase? At present it is not possible to give exact answers to these questions. On the basis of indirect data it is believed that in the first stage of selective cultivation of land leading to a sharp increase in the mosaic of the landscape there may be an increased potential danger from alveococcus. Further land cultivation would perhaps lead to neutralization of the environmental prerequisites of this danger.

So the forest steppes and steppes of the USSR should be considered as being potentially exposed to infection by alveococcus. However, the degree of this danger and accordingly the risk of infection to the human population varies according to the regional peculiarities of the landscapes or location within areas where there is a vertical zonal belt. The danger is greater when the parasite is present in large numbers of polar foxes spread over a wide area. The factor determining the degree of danger is the amount of moisture in the soil which in its own turn is related to the nature of the relief and to the peculiarities of surface drainage. The flat lands of the forest steppes of western Siberia and northern Kazakhstan and those near the Altai Mountains, Salair, Kuznetsk, Alatyr and Sayan are potentially very dangerous. The flat lands around the hills in the forest steppes and steppes of Preduralya, central Siberia, Zabaikal, western Siberia, Kazakhstan, Tyan'Shanya, southern Siberia and Prebaical may be considered as natural territorial complexes with a medium degree of danger. Finally the forest steppes and steppes of the Great Russian Plain and the hill steppes of Zacaucacious may be considered as having a low degree of danger.

Arid and Semi-Arid Landscapes: The ecology of alveococcus in this zone is determined not only by a typical parasitic system but also by the peculiarities of the water temperatures of arid landscapes. The parasitic system is made up of foxes, which predominate, and the types of rodents found in arid areas, mainly the desert rat and the jerboa. In spite of the high and relatively constant numbers of the species that host the parasite in these regions its density is very low. This can be seen from the results of helminthological research on the definitive and intermediate hosts. Surveys of foxes in various parts of Uzbek revealed that the infection was of very low density in isolated animals, constituting 0.5% to 3.3% of the total number examined; of a total number of 2,000 dogs examined, alveococcus was found in only two or 0.1% [108, 370, 371, 372]. During helminthological examinations of polar foxes [93, 359, 372], korsaks [95] and dogs [313, 359] alveococcus was found in isolated instances in Azerbaydzhan, Uzbekistan, Tadzhikistan and Turkmenia. Surveys conducted in these regions on wild and domestic canines showed alveococcus to be absent [77, 83, 360, 368, 373]. Surveys of several thousand rodents (mainly the large and red-tailed desert rats, the small jerboa, the house mouse, etc.) in the arid regions of Kazakhstan, Kirgizskaya and Azerbaydzhan to ascertain whether alveococcus was present in the larval stage [61, 77, 266, 287, 289] also gave negative results with the exception of isolated instances among the small jerboa and large desert rats. A somewhat higher level of infection [1% to 3%] was found among the large desert rats in the semi-arid regions of the middle reaches of the River Emba and among the common field voles in Armenia [127, 403].

This low incidence of the parasite in arid landscapes given the high population of potential hosts once again confirms the importance of the external conditions encountered by the eggs of alveococcus when they are outside the body of a host. Very high temperatures and many hours of sunlight, very little rain, almost no surface drainage and very little vegetation all lead very quickly to the loss of the infective ability of the eggs of alveococcus in these regions. For this reason the biocenotic relationship between the numbers of sexually mature alceocccci and the rodents inhabiting these area is severed. The great ovicidal effect of the environment almost completely neutralizes the high reproductive ability of the parasite. Only under comparatively better living conditions is this death cycle interrupted and new types of hosts infected. These are to be found, firstly, in the intra-zonal areas of lakes and tributaries of large rivers and in the hills where the humidity is slightly higher due to the altitude and the varied nature of the relief. In these areas animals infected with alveococcus contaminate the environment to a considerable degree. For instance, around the Aralskoye complex of lakes 25% of the polar foxes and dogs are infected with alveococcus when contamination is at its highest [8, 103]. The number of dogs infected near the hills of Dzungarskiy Ala Tau is lower: about 1.5% [14]. The incidence of larval alveoccccus in the musk rat around the Aralskoye, the tributaries of the Ili and the Syr Darya, varies appreciably, reaching a maximum of

9.4% [8, 103, 287, 332].

It seems likely that semi-arid regions with their extremely mosaic relief, moist soil and fairly dense vegetation present rather favorable conditions for the proliferation of the parasite. This can be seen, for example, from helminthological examinations of canines and rodents carried out in the semi-arid region between the Volga and Ural Rivers where the concentration of polar foxes was found to be among the densest.

To summarize, we may say that in spite of their having a very high concentration of polar foxes arid landscapes are not potentially very dangerous areas as far as alveococcus is concerned. The discrepancy between the large numbers of polar foxes and the insignificant number of them infected with alveococcus is explained by the very unfavorable conditions that the egg of the parasite endures in such environments. It is also explained by the insignificant incidence of larval alveococcus among rodents inhabiting arid landscapes (desert rat and jerboa) and its sharp increase during transition to different species which are associated with moist intra-zonal biotypes (musk rat). The epidemiological significance of dogs in arid regions is small, most probably due to their limited ability to infect and to the still prevailing custom of avoiding contact with dogs because they are considered to be dirty animals. The epizootic process is somewhat intensified and so is the risk of infection in the intra-zonal areas and in hilly regions.

This brings us to the conclusion that as far as geographical environment is concerned, alveococcus is a zonal disease. To thrive it requires moderately moist, open spaces (tundra, forest tundra, some regions of taiga, forest steppes and steppes). In these environments, which have some characteristics in common, there are two factors governing the potential danger alveococcus poses both to the landscape and to humans; a high population of wild canines (or even domestic dogs) and conditions that permit prolonged preservation of the infecting potential of the eggs of the parasite after they have been excreted by the host.

In the USSR four kinds of territorial complexes, differing from each other in the degree of potential danger they face from alveococcus, have been defined.

The qualitative evaluation of this danger with regard to given territories has been depicted in the map, where we have tried to show the distribution and frequency of alveococcus in animals. Centers where surveys have been carried out are marked with signs, space permitting. Direct evaluation of the potential danger from alveococcus in certain regions of the USSR has been difficult because of lack of data on alveococcal infections in wild animals. In these cases circumstantial data alone have been used (susceptibility of the local inhabitants to infection, isolation of the causative organisms in farm animals and the environmental characteristics of the regions concerned), comparing them with geographically similar areas that have provided helminthological material. Though this approach may not give a very exact and detailed picture, on the whole it offers a fairly good summary of our knowledge of the geography of alveococcus which may serve as a starting point for future research on the subject.

Where the natural prerequisites of alveococcus have been realized? What role do the landscape requirements of alveococcus and their influence on the danger it poses to a territory play in the occurrence of this disease in man?

It is not easy to answer this question. This is because very meager information is available about alveococcus infection of man. This information refers to the territories of northern Kirgizia [282, 283], Barabinsk, Novosibirsk and the Vilyuusk region of Yakutsk [309]. Under these circumstances there is no way out other than to reprocess the information that is available on the incidence of the disease from clinical, pathological and anatomical data.

As we have already said, these data present a depressing picture, which is apparent when a cartographical interpretation is attempted. This is probably because the cartographical method is so specific. Verbal descriptions of a territory or the territorial distribution of a particular phenomenon of necessity take time, whereas when the facts are presented cartographically the whole picture is conveyed in one shot, much as it would be in real life. But this wonderful aspect of a map, which N.N. Baranski emphasized in his day, requires that the data it presents be in one form. As far as the infection of man by alveococcus is concerned, these factors compelled us to look for a common denominator whereby the clinical, pathological and anatomical data that have accumulated in the literature since the turn of the century could be presented. As it is not possible to describe all the details of these processes we will give only the end results in the form of basic facts that were used to illustrate the data. These may be summarized as follows;

A) With a view to unifying the clinical material, the number of cases of alveococcus in man recorded in one administrative territorial unit were taken for a period of five years. This time period was selected because all the data available represented at least five years' findings.

B) Based on the figures so obtained, an index of the disease per 100,000 of the population within a corresponding administrative territorial unit was drawn up.

C) For sparsely, unevenly populated territories (the north and northeastern desert regions of central Asia, etc.) contours were drawn where the population density increases by one man per square kilometer; data on the population of farm workers and their succeptibility to infection was shown within these contours. Thus the figures of the incidence of the disease appear in the map as being lower than they actually are, but taken in the light of the little information available on alveococcus this inaccuracy is insignificant.

D) The incidence of alveococcus has been given in percentages of the whole within the boundaries of sparsely populated territories. Mapping of clinical data has been done in the same way.

E) Depending on the incidence of the infection and on the pathological and anatomical details of the disease, the available data for a territory have been graded in three slabs. Numerical gradations are given in the legend of the map.

From the mapping and analysis of these data, it could be seen clinically that at present 47 administrative territorial units of the USSR are infected with alveococcus. Pathological and anatomical data are available on 21 regions of the country. Of these, no clinical data has been published on five. As a result, information is available on the environmental requirements of alveococcus for at least 52 administrative units of the country. Cartographic analysis of clinical, pathological and anatomical material, when compared with the geographical factors governing the natural locations congenial to this disease, shows that the territorial distribution of alveococcus in general corresponds to the factors we mentioned earlier for evaluation of the potential danger of a given geographical environment and the risk of infection to which man is exposed.

In our map alveococcal infection of the population has been depicted by dots. The levels of intensity of the infection were determined on the basis of standard indices of the disease at the time of analysis of the incidence of alveococcus according to pathological and anatomical findings.

The main results of this work are given below and an attempt has been made to explain certain deviations which occurred during the process of cartographic analysis of the potential danger to the landscape and the incidence of the disease among the human population. Analysis of the material dealing with alveococcal infection of the human population of the extreme north and northeast /̲¯16, 28, 49, 50, 53, 264, 275, 292, 293, 311, 330, 334, 408_̸/ showed that the highest incidence of this disease on a countrywide scale is found in this region. It is highest in Chukotskii and next in Vilyuskaya and central Yakutsk (108 to 120 cases per 100,000 of the population in an average of five years). Then follows Kamchatka (78 cases), the Lensko Olekminskaya areas of Yakutsk /̲¯54_̸/, the northern Evenskii area of Magadanskaya /̲¯42_̸/, and the Kolymskii and Oymyakonsk areas of Yakutsk (31 and 26 cases respectively). In Yakutsk the highest incidence of alveococcus was 1.3%. Its incidence in the Krasnoyarsk region (13 cases per 100,000) and particularly in the Tyumensk region /‾2_7 is very low. In actual fact its incidence in these regions may be higher (pathological findings show a high incidence of alveococcus in Tyumensk (0.44%), which supports this surmise) but for a number of reasons the available data do not reflect this clearly. It is imperative that these regions receive the attention of the specialists in the field because of the great economic potential of Siberia. This also applies to northern Europe, which has not yet been surveyed for alveococcus in man. Thus the data presently available confirm that the peculiarities of the landscape of the extreme north and northeast of the USSR make it very vulnerable to alveococcus. The link between landscapes favorable to alveococcus and the high rate of infection of man in those landscapes certainly has something to do with the way of life and occupations of the inhabitants. This becomes particularly clear from the meager data available on the composition of infected categories /‾27, 309, 310_7.

The second-highest incidence of alveococcus in man is found in regions where forest steppes and steppes predominate. Southwestern and central Siberia, Altai and the adjoining regions of Kazakhstan and also northern Kirgizsyaya are such regions. Analysis of the data on these areas shows /‾22, 27, 61, 74, 91, 272, 278, 282, 283, 289, 299, 300, 301, 305, 306, 308, 324, 327, 329, 348, 349, 376, 380, 384 and 407_7 that the infection is present in the range of 2 to 18 cases per 100,000 of the population in an average of five years. The highest incidence is recorded in the hilly autonomous regions of Altai, Novosibirsk, south of Krasnoyarsk, followed by west Kazakhstan and Chelyabinsk, the plains and foothills of the Altai region (6 to 8 cases) and lastly

Semepalatinskaya, Kurganskaya, Omsk, southern Tomsk and Irkutsk regions falling under the republics and to some extent the former Tyan-shan regions of Kirgiz SSR (2 to 4 cases). The incidence of alveococcus, according to pathological and anatomical findings, only partly tallies with these figures. This is to be expected because for one and the same region and for the same periods of time different authors reported different incidence figures in the sectional material.

For example, I.L. Bregadze and V.M. Konstantinov [278], referring to I.M. Kagalovskoi's data for the period 1949-1959, indicate an incidence of 0.85% infection in the Novosibirsk region while in their own data for the same region for the period 1953-1957 they report the incidence of alveococcus as being 0.40% [277]. Taking the average of the figures published by different authors for one and the same region it would seem that the occurrence of alveococcus in the Novosibirsk region was 0.63%, in the Tomsk region 0.51%, in the Tyumensk region 0.44%, in the Kirgiz region 0.30%, in the Chelyabinsk region 0.20% and in the Omsk region 0.13%.

This cannot be even remotely substantiated by the literature available today on the infection of man by alveococcus. Moreover, there would most certainly be variations in the levels of infection within these administrative units, inclining to one side or the other of the average worked out for them.

This is very clearly illustrated in A.F. Protasova's data [363] on the Kirov region. Taking the region as a whole, she found that the incidence of alveococcus was 0.85%. However, the great majority of cases came from six eastern areas where the frequency of infection comes to 3.72% as against 0.28% in the remaining 18 regions. The frequency as recorded by the author from data covering the last 17 years is respectively 14 and 1 per 100,000 of the population, calculated for a five year period this works out to 4.1 and 0.3 respectively. The reasons for this distribution of disease are not discussed by the author, though its dependence on the density of polar foxes and musk rat has been mentioned.

Returning to the regions of Siberia and Kazakhstan, it can be assumed that the actual figures for frequency of the infection are higher than the ones we have today. This view is partly confirmed by a definite discrepancy in the parameters of the parasitic system in the forest steppes, indicating a high degree of potential danger (as has been shown in the map). It is further confirmed by results of a selective, complex check of the population in the forest steppes region of western Siberia [72], where a positive reaction of Katstsoni was registered in 2.3% of the people examined. A still higher (3.6%) number of positive results was observed in occupational groups which were exposed to greatest risk of infection (hunters, agricultural and animal husbandry workers, etc.). A considerable portion of those giving a positive reaction had an enlarged trabiculated liver, a symptom that leads one to suspect alveococcus.

Thus an average level of infection of alveococcus is to be found in the Asian part of the USSR where the landscape is predominantly forest steppes and steppes. The widely reclaimed forest areas of Preduralye (to the southwest of the Kirovsk region) can be included here. Possibly the lowest levels of infection are to be found in the forest steppes, steppes and mountainous steppes of central Povolzhye (Tatarsk ASSR), south Preduralye, Bashkirskaya ASSR and southwestern Kazakhstan (Alma-Ata and the former Taldy Kurgan regions). On the basis of available material on the number of people infected with alveococcus [31, 61, 297, 308, 318, 319, 364], the incidence appears to be lower than 2. However, this could very well be put down to incomplete data or more specifically to the fact that from the results of pathological and anatomical findings the frequency of alveococcus in this region appears to vary from 0.19% to 0.70% [7, 20, 122, 279, 377, 406]. But even taking into consideration the fact that in certain regions of the territories mentioned the incidence of infection may be higher than today's figures show, it is still arguable that the level of infection of the population by alveococcus, in general, corresponds with the degree of potential danger characteristic of the predominant landscapes of steppe regions of this kind.

The lowest figures for the infection of man by alveococcus take in about half the total number of administrative territorial units where clinical, pathological and anatomical data are available. Analysis and cartography of this material show [567, 10, 12, 16, 27, 32, 45, 61, 77, 78, 90, 286, 291, 296, 298, 299, 308, 323, 340, 343, 351, 352, 361, 362, 370, 372, 379, 385, 389, 390, 400] that the incidence of infection varies in these areas from 1.6 to 0.01 per 100,000 of the population in an average of five years and the frequency of alveococcus shown by all pathological and anatomical findings is 0.06 to 0.005%. Examination of this group of administrative units brings one to the conclusion that they comprise territories having very different characteristics and the lower incidence of the disease there has a variety of causes.

For certain regions and republics the lower level of infection by alveococcus corresponds with the degree of potential danger of the natural environment. In many regions of Kazakhstan (Dzhambul, Guryev, Karaganda, Aktyubinsk, Kzyl, Orda, south Kazakhstan) the disease is at the level of 1.6 and 0.6 and according to pathological and anatomical findings it registers 0.06% or is not found at all. Turkmeniya, Armyanskaya, Azerbaydzhan, Gruzinskaya SSSR and the Osh region of Kirgiz fall into this category, where the infection is 0.5 to 0.03. In Uzbekskaya and Tadzhikskaya SSR the level of infection is 0.02 to 0% (pathological and anatomical findings 0.06 to 0.02%). This low level of infection in these regions may be due to the predominance of semi-arid and arid landscapes which do not present a very high risk of infection. In some places, the very high density of the population and widely cultivated lands may also have a bearing on the low level of infection. This is also probably true of the reclaimed steppes south of the Great Russian Plain and Precaucasus. Thus in the Stavropol region the infection is at the 1.4% level, in the Kuybyshevsk region it is 0.17%; in Chechen-Ingushsk ASSR ... it is 0.09, in the Krasnoyarsk region it is 0.04 and in the Dnepropetrovsk, Kharkovsk and Zaporozhsk regions of the Ukrainian SSR it is 0.01%.

Some of these lower figures (Khabarovskya 1.1, Pavlodarskaya 0.2 and Buryatskaya ASSR 0.12) and the negative results obtained from clinical and pathological material in other regions (north Caucasian and Amurskaya region, Dagestan ASSR) evoke some doubts and point to the necessity of further research.

In Tuvinsk ASSR, Chitinskaya and certain regions of far eastern Russia (north of the Khabarovsk region, the Sakhalinskaya region, including the Kurile Islands), it is possible that the infection of the population is higher than has been recorded.

An attempt has been made in this work to examine the distribution of alveococcus in the USSR taking into account the various influences that the geographical environment has on the structure of the Noso area. Man's fight against alveococcus is certainly not an easy one. The problem is complex and all the institutions concerned with its treatment should join together to solve it. Methods of treatment and prophylactic measures should be adapted and modified taking into account the peculiarities of the places where it is established that alveococcus is epizootic and endemic.

Many questions remain to be solved concerning this disease and this work may be helpful not only as a first experiment in evaluating the 'carrying capacity' of landscapes but also as an informational base for detailed surveys of various republics, provinces and other regions of the USSR.

V

GENERAL

The distribution of alveococcus in the USSR has been examined from the point of view of the influence various factors of the geographical environment have on the structure of the noso area. The environmental requirements of alveococcus have been discussed in relation to different landscapes zones of the USSR. The local peculiarities of the disease have been described taking into account the peculiarities of the structure of the noso area.

Information on surveys on alveococcus in the USSR and a map of the environmental requirements and distribution of the disease are provided.

Appendix. Cadaster data on Alveococcosis in animals and man in the USSR

Territory	Reference	Year of observation	Alveococcus infection of definitive and intermediate hosts									
			Wild and domestic canines				Rodents and domestic artioxactyls				Man	
			Species	Investigated specimens	Infected		Species	Investigated specimens	Infected		Patients (absolute number for the period of observation)	Reported from slides (in % of the total No. of section)
					Absolute	%			Absolute	%		
1	2	3	4	5	6	7	8	9	10	11	12	13
			European part of the USSR									
Murmansk region												
Kal'din Island	358	-	Polar fox	+	+	+	-	-	-	-	-	-
Novaya Zemlya Island	358	-	Polar fox	+	+	+	-	-	-	-	-	-
Nenetskii national district (Coast of Kara Sea, basins of Kara, and Sibiricha rivers and lower reaches of Pechora river)	124	-	Polar fox	55	27	49	-	-	-	-	-	-

1	2	3	4	5	6	7	8	9	10	11	12	13
Nenetskii national district												
(neighborhood of Khorei-	11		Polar fox	13	8	-						
Vera and Khoseda-Kherd)	118	1968	Fox	3	0	0	-	-	-	-	-	-
Kostromsk province	312	-	-	-	-	-	Hare	+	1	+	-	-
Kirovsk region	363	1948-1963	Fox	15	0	0	Hare	4	0	0	-	0.70
Brest region (Luninetesk												
district)	344	-	-	-	-	-	Field rat	+	1	+		-
Vitebsk, Smolensk,	307,											
Ryazan', Moscow,	341,											
Tula, Orlovsk, Penza	342,											
Provinces	347	1890-1910	-	-	-	-	-	-	-	-	9	-
Gorkii region (left bank												
region) Tatar and						10.7						
Chuvash ASSR	367	1956-1962	Fox	372	-	0	-	-	-	-	-	-
Gorkii region	295	1891-1947	-	-	-	-	-	-	-	-	-	0.04
Tatar ASSR	279	-	-	-	-	-	-	-	-	-	-	0.48
Tatar ASSR	406	-	-	-	-	-	-	-	-	-	-	0.40
Bashkir ASSR	297	1936-1938	-	-	-	-	-	-	-	-	26	-
Bashkir ASSR	20	1936-1940	-	-	-	-	-	-	-	-	-	0.70
Bashkir ASSR	318	1944-1948	-	-	-	-	-	-	-	-	14	-

1	2	3	4	5	6	7	8	9	10	11	12	13
Bashkir ASSR	319	1936–1944	-	-	-	-	-	-	-	-	81	-
Bashkir ASSR	122	1946–1956	-	-	-	-	-	-	-	-	-	0.27
Bashkir ASSR	31	1951–1960	-	-	-	-	-	-	-	-	27	-
Kursk region (Mikoyanovsk district)	-	-	-	-	-	-	Draft cattle	-	1	-	-	-
Sumsk region (Akhtyrsk district)		-	-	-	-	-	Draft cattle	-	1	-	-	-
Kharkov region (Krasnokutsk, Ballakleevsk, Zolochevsk, Bogodukhovsk, Zmievsk, Dergachevsk districts)	356	-	-	-	-	-	Draft cattle	-	6	-	-	-
Dnepropetrovsk region (Nikopolsk district)		-	-	-	-	-	Draft cattle	-	2	-	-	-
Pollavsk region (Zin'kovsk district)		-	-	-	-	-	Draft cattle	-	2	-	-	-
Kharkov	343	-	-	-	-	-	-	-	-	-	1	-
Dnepropetrovsk, Zaporozh'e, Kharkov regions	389	1925–1960	-	-	-	-	-	-	-	-	2	-
Balashevsk region, Kikvidzensk district	395	- -	-	-	-	-	Field rat (?)	18	1	-	-	-

1	2	3	4	5	6	7	8	9	10	11	12	13
Kuibyshev region	361	1935–1952	–	–	–	–	–	–	–	–	5	–
Moldavian SSR, regions	45	1950–1958 ?	–	–	–	–	–	–	–	–		–
Tirnovsk											1	
Synzheroisk											1	
Benderovsk											2	
Tarakliisk											2	
Kagulsk											5	
Kishinevsk											7	
Donetsk	290	–	–	–	–	–	–	–	–		2	–
Rostov-on-Don	400	1918–1927	–	–	–	–	–	–	–		–	0.03
Rostov-on-Don	343	–	–	–	–	–	–	–	–		1	–
Rostov-on-Don	352	–	–	–	–	–	–	–	–		2	–
Crimea (different districts)	314	–	Fox	110	–	1–9	–	–	–	–	–	–
Crimea	351	–	–	–	–	–	–	–	–	–	2	–
Stavropolsk Krai	291	1921–1925	–	–	–	–	–	–	–	–	15	–
Krasnoyar Krai (Krylovsk, Kalininsk, Otradnensk, Labinsk, Spokoensk districts) Stavropotsk Krai (N-Aleksandrovsk, Nevinnomysk districts)	528	–	–	–	–	–	Goats, sheep	1300	10	0.1	–	–

1	2	3	4	5	6	7	-	9	10	11	12	13
Krasnoyar Krai	390	1921-1925	-	-	-	-	-	-	-	-	1	-
Pyatigorsk	323	1924-1930	-	-	-	-	-	-	-	-	5	-
Dagestan ASSR (Buinaksk	354	-	Dog	181	1	0.55	-	-	-	-	-	-
district)	355		Fox	6	1	-						
Makhachkala	409	-	Dog	133	+	+	-	-	-	-	0	0
Makhachkala	411	-	Dog	-	1	-	Agricultural animals	+	0	0	-	-
Dagestan ASSR	410	-	Dog	+	+	+	Rodents	+	0	0	0	0
			Fox	+	+	+	animals	+	+	+		
Dagestan ASSR	10	1952-1963	-	-	-	-	-	-	-	-	0	-
Chechen-Ingush ASSR	6	1939-1959	-	-	-	-	-	-	-	-	2	-
							Transcaucasian republics					
Georgean SSR (Tsiteltkaroisk district)	63	-	Fox	+	+	+	Domestic vole	+	+	+	-	-
Georgean	362	1913-1936	-	-	-	-	-	-	-	-	5	-
Azerbaijan SSSR												
Kurinsk lowland, hills and foothills (Kut-			Fox	11	0	0	Coypu	37	0	0		
koshensk, Zakatalsk,			Jackal	27	0	0	Water rat	27	0	0		
Ismailinsk districts)	373	-	Wolf	3	0	0					-	-

1	2	3	4	5	6	7	8	9	10	11	12	13
Azerbaijan SSR, regions:												
Akhsuinsk, Shemakhinsk	77	1950–1961	-	-	-	-	-	-	-	-	2	-
Apshereronsk			-	-	-	-	-	-	-	-	2	-
Ali-Bairamalinsk			-	-	-	-	-	-	-	-	2	-
16 others			Dog	240	0	0	Cattle	+	0	0	0	0
Azerbaijan SSR (Shongorsk, Apsheronsk, Khachamassk, Lenkoransk, Ali-Bairamalinsk districts)	77	-	-	-	-	-	Red-tailed desert vole, domestic vole, common vole, lesser Jerboa, house rat, etc.	8097	1*	-	-	-
Azerbaijan SSR (Negornyi Karbakh, Kel'bedzharsk districts)	298	1900–1932	-	-	-	-	-	-	-	-	7	-
Azerbaijan SSR	359	-	Fox	+	+	+	-	-	-	-	-	-
Azerbaijan SSR and Georgean SSR	368	-	-	-	-	-	Coypu	157	0	0	-	-
Armenian SSR, different districts	32, 78, 286	1922–1962	-	-	-	-	-	-	-	-	14	-

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* Lesser Jerboa

1	2	3	4	5	6	7	8	9	10	11	12	13
Armenian SSR (Amasiisk district	403	1964	-	-	-	-	Common vole	180	2	1.1	-	-
			Western Siberia									
Tyumen' region (Yamal peninsula)	66	-	Fox	104	85	82	Ob lemming, hoofed lemming, narrow-headed field vole, Middendorf field vole	104	0	0	-	-
Tyumen' region (Yamal peninsula)	326	-	-	-	-	-	Ob lemming	+	+	+	-	-
Tyumen' region (Yamal peninsula)	71	-	Polar fox	153	47	31	-	-	-	-	-	-
Tyumen' region (Yamal peninsula)	402	-	Polar fox	59	30	51	-	-	-	-	-	-
Tyumen' region (Transural and northern Ob')	33, 359	-	-	-	-	-	Ob lemming, musk rat, field vole, *Microtus oeconomus*	+	+	+	-	-

1	2	3	4	5	6	7	8	9	10	11	12	13
Tyumen' region (Southern and transpolar districts)	49	1953–1962	–	–	–	–	–	–	–	–	27	0.44
Tomsk region	272	1894–1916	–	–	–	–	–	–	–	–	27	–
												0.43
												0.40
Tomsk region	407	1908–1958	–	–	–	–	–	–	–	–	100	–
Tomsk region	197	–	Dog	+	+	+	–	–	–	–	–	–
Chelyabinsk region	380	1950–1960	–	–	–	–	–	–	–	–	53	–
Chelyabinsk region	324	1947–1956	–	–	–	–	–	–	–	–	–	0–20
Chelyabinsk region (Magnitagorsk district)	343	1954–1965	–	–	–	–	–	–	–	–	63	–
Chelyabinsk region (Troits, Krasnoarmeisk districts)	374	1953–1955	Fox	–	–	70	Musk rat	164	9	5.5	–	–
Kurgansk region	332	–	–	–	–	–	Musk rat	289	–	2.4	–	–
Kurgansk region	325	1960–1962	Fox	50	6	12	–	–	–	–	–	–
			Dog	109	1	0.9	–	–	–	–	–	–
Kurgansk region (mostly Vargashinsk, Lebyazhevsk, Chashinsk, Petukhovsk, Kurtamyshevsk districts)	305	1947–1965	–	–	–	–	–	–	–	–	37	–

1	2	3	4	5	6	7	8	9	10	11	12	13
Omsk region												
Taiga					-	2	Musk rat					
Forest steppe	315	1951-1959	Fox	865	-	40	Common vole	+	+	+	-	-
Steppe					-	35	Bank vole					
Omsk region	316	-	Wolf	11	4	-	Bank vole	-	-	1.5	-	-
			Dog	126	0	0	Common vole	-	-	5.0	-	-
Omsk region (Kurtinsk, Nazyvaevsk, Tyukalinsk districts)	317	1958-1960	-	-	-	-	Musk rat	-	-	5.25	-	-
Omsk region	91	1941-1962	-	-	-	-	-	-	-	-	77	0.1
Omsk region (18 districts)	348	1958-1960	-	-	-	-	-	-	-	-	25	-
Novosibirsk region, entire including	277	1955-1957	-	-	-	-	-	-	-	-	64	0.4
Barabinsk district			-	-	-	-	-	-	-	-	22	-
Eastern district			-	-	-	-	-	-	-	-	21	-
North Kulunda (4 districts)			-	-	-	-	-	-	-	-	8	-
Novosibirsk agricultural district			-	-	-	-	-	-	-	-	7	-

1	2	3	4	5	6	7	8	9	10	11	12	13
Other districts			-	-	-	-	-	-	-	-	6	-
Northern districts			-	-	-	-	-	-	-	-	0	-
Novosibirsk region	278	1949-1953	-	-	-	-	-	-	-	-	-	0.85 Date of the regional hospital
Novosibirsk region 24 districts (as per list) with 2-5 cases in each district	329	1950-1960	-	-	-	-	-	-	-	-	106	-
Novosibirisk region (mostly Barabinsk district and Kulunda)	276	1953-1957	-	-	-	-	-	-	-	-	69	-
Novosibirisk region Barabinsk district	64	1954-1958	Dog	36	0	0	Musk rat	334	6	1.3	11	-
							Red vole,	328	0	0		
							Microtus oeconomus	274	1	0.4		

1	2	3	4	5	6	7	8	9	10	11	12	13
Malinsk district			-	-	-	-	*Microtus oeconomus*	10	2	-		
							Red vole	56	6	11	-	-
Novosibirsk region Barabinsk district	72	1959	-	-	-	-	Water rat,	1715	0	0	-	-
							voles of 8 species,	1188	50	4.2	10	-
							Draft cattle	+	0	0		
Novosibirsk region Barabinsk district	67	1959-1960	Dog	81	2	2.4	Field rat	17	7	-	-	-
			Fox	335	146	43	*M.oeconomus*	77	6	7.8		
			Wolf	5	4	-	Narrow-headed vole	175	1	0.6		
							Red vole	157	6	3.8		
							Musk rat	1160	36	3.1		
Altai Krai, entire; including 21 districts (see list) with 2-5-7 cases in each district and 25 districts (see list) with 1 case in each	327	1957-1960	-	-	-	-	-	-	-	-	99	-

1	2	3	4	5	6	7	8	9	10	11	12	13
						Kazakhstan						
North Kazakhstan region, Mamlyutsk district	388	1956	-	-	-	-	Musk rat	38	-	6.5	-	-
Pavlodar district	90	1950-1961	-	-	-	-	-	-	-	-	4	-
Pavlodar	308	1929-1940	-	-	-	-	-	-	-	-	2	-
Pavlodar	61	1957-1958	-	-	-	-	-	-	-	-	0	-
Petropavlovsk	61	1905-1935	-	-	-	-	-	-	-	-	0	-
Kustanai region, Fedorovsk and Peshkov districts	96	-	-	-	-	-	Draft cattle	-	-	0.6	-	-
							Sheep	-	-	0.46	-	-
Kustanai region	102	- -	Fox	4	1	-	Draft cattle	2006	1	0.05	-	-
							Swine	3531	1	0.03	-	-
Akmolinsk region	84	-	-	-	-	-	Swine	+	+	+	-	-
Akmolinsk region (Atbasarsk and Kurgaldzhinsk districts)	320	-	Fox	20	4	-	-	-	-	-	-	-
Akmolinsk region	382	-	Korsak	17	5	-	-	-	-	-	-	-
Akmolinsk region	396	1955-1965	Korsak	-	-	30	Musk rat	-	-	2.8-9.5	2	-
Gur'ev	308	1929-1940	-	-	-	-	-	-	-	-	4	-
Aktyubinsk	308	1929-1940	-	-	-	-	-	-	-	-	3	-

1	2	3	4	5	6	7	8	9	10	11	12	13
Uralsk region	61	1923-1940	-	-	-	-	-	-	-	-	0	-
Aktyubinsk region (mid reaches of Emba river)	127	1959	-	-	-	-	Big desert vole	1100	33	3	-	-
Karaganda region	61	1947-1952	-	-	-	-	-	-	-	-	3	-
Karaganda region (Voroshilovsk, Zhana-Arkinsk, Karakitinsk, Ozakarovsk districts)	40	-	-	-	-	-	Sheep	5135	1	3.1	-	-
Karaganda region	385	1948-1952	-	-	-	-	-	-	-	-	3	-
Semipaletinsk region (Zharminsk, Kokpektinsk, Ayaguzsk, N. Shul'binsk, Abaevsk and Charsk districts)	22,23	1940-1958	Fox	3	1	-	Sheep	-	-	1.8	23	-
			Dog	112	1	0.9	Draft cattle	-	-	1.6		
Semipalatinsk region	306	1952-1957	-	-	-	-	-	-	-	-	5	-
Ust-Kamenegorsk region	384	1953-1957	-	-	-	-	-	-	-	-	19	
Ust-Kamenegorsk region (Leninogorsk city)	61	1956-1958	-	-	-	-	-	-	-	-	3	-

1	2	3	4	5	6	7	8	9	10	11	12	13
East Kazakhstan region (Semara, Katon-Karagaisk districts)	61	1959	-	-	-	-	Long-tailed henster	67	0	0	-	-
							Wood mouse	38	0	0		
							Field vole	17	0	0		
							Common vole	13	0	0		
Kzyl-Ordin region	7	1941-1957	-	-	-	-	-	-	-	-	-	0.06
South Kazakhstan region	7	1941-1957	-	-	-	-	-	-	-	-	-	0.06
Kzyl-Ordin region	287	-	-	-	-	-	Musk rat	220	2	0.9	-	-
							Large desert vole	Many thousands	1	-	-	-
Dzhambulsk region	7	1941-1957	-	-	-	-	-	-	-	-	-	0
Dzhambul	308	1929-1940	-	-	-	-	-	-	-	-	11	-
Dzhambulsk region	42	-	-	-	-	-	Sheep	+	+	+	-	-
Alma-Ata	308	1929-1940	-	-	-	-	-	-	-	-	11	0.41
Alma-Ata	337	1935-1939	-	-	-	-	-	-	-	-	-	0.43
Alma-Ata	61	1950-1957	-	-	-	-	-	-	-	-	6	-
Alma-Ata	369	1937-1941 1945-1949	-	-	-	-	-	-	-	-	22	-

1	2	3	4	5	6	7	8	9	10	11	12	13
Alma-Ata region	7	1941-1957	-	-	-	-	- -	-	-	-	-	0.23
Taldy-Kurgan region	7	1941-1957	-	-	-	-	-	-	-	-	-	0.19
Alma-Ata region, districts	8	1959										
Alakul'sk			Fox	20	5	-	Musk rat	3041	-	0.5-9.4	6	-
Balkhashsk			-	-	-	-	Musk rat	2213	2	$0.\overset{0}{9}$	-	-
Alma-Ata region (Alakul'sk district)	103	1961	-	-	-	-	Musk rat	203	4	2	-	-
		1962	Fox	3	1	-	Musk rat	1658	-	1.5-4.7	-	-
			Dog	16	4	-	Water rat	279	0	0	-	-
Taldy-Kurgan region	14	1958-1959	Dog	+	+	2-3	Sheep	-	1	-	-	-
Alma-Ata region (Bakanask district)	61	1959	-	-	-	-	Large desert vole	1417	0	0	-	-
						Central Asian Republics						
Turkmenian SSR	93	-	Dog	+	+	+	-	-	-	-	-	-
Turkmenian SSR	12	-	-	-	-	-	-	-	-	-	8	-
Uzbek SSR (Different landscape zones)	83	1959-1961	Fox	98	0	0	-	-	-	-	-	-
54 districts of the republic	108	1959-1962	Dog	678	1	0.15	-	-	-	-	-	-

1	2	3	4	5	6	7	8	9	10	11	12	13
17 districts of the republic	108	1959–1962	Fox	189	1	0.5	-	-	-	-	-	-
Samarkand region (Samarkand, Nuratin, Urgutsk, Dzhanbaisk districts)	340	1931–1947	-	-	-	-	-	-	-	-	-	0.04
Samarkand region	370	1930–1962	Dog	1124	1	0.08	Sheep	47,745	12	0.025	6	0.08
							Draft cattle	5,855	8	0.14		
							Swine	11,655	1	0.009		
Ferghana region	370	-	-	-	-	-	Draft cattle	275	1	0.3	-	-
Andizhan region	370	-	-	-	-	-	Draft cattle	72	1	1.4	-	-
Sukhandarin region	370	-	Fox	30	1	-	Sheep	450	1	0.2	-	-
Bukhara region	370	-	-	-	-	-	Sheep	212	1	0.5	-	-
Andizhan, Ferghana, Namangan region	5	1950–1959	-	-	-	-	-	-	-	-	2	-
Samarkand, Ferghana, Andizhan, Namangan, Kokand, Magalan, Karshi cities	108	1959–1962	Dog	654	1	0.15	-	-	-	-	-	-
Tadzhik SSR	359	-	Korsak	+	+	+	-	-	-	-	-	-

1	2	3	4	5	6	7	8	9	10	11	12	13
Tadzhik SSR	360	-	Wolf	2	0	0	-	-	-	-	-	-
			Jackal	24	0	0	-	-	-	-	-	-
			Fox	9	0	0	-	-	-	-	-	-
Tadzhik SSR	379	1935–1940	-	-	-	-	-	-	-	-	-	0.2
Tadzhik SSR	278	-	-	-	-	-	-	-	-	-	0	-
Kirgiz SSR	289	1940–1945	-	-	-	-	-	-	-	-	14	-
Kirgiz SSR	74	1955–1959	-	-	-	-	-	-	-	-	-	0.30
Kirgiz SSR entire	299	1936–1963	-	-	-	-	-	-	-	-	-	0.16
Northern districts	299	1936–1963	-	-	-	-	-	-	-	-	60	-
Southern districts	299	1936–1963	-	-	-	-	-	-	-	-	0	-
Northern Kirgizia	282	1940–1955	-	-	-	-	-	-	-	-	66	-
Northern Kirgizia	283	1940–1955	-	-	-	-	-	-	-	-	54	-
Southern Kirgizia	27	1945–1959	-	-	-	-	-	-	-	-	0	-
Issyk-Kul' region (Issyk-Kul, Przhevalsk, Pokrovsk districts)	289	1956	-	-	-	-	Susliks	359	0	0	-	-
							Hares	12	0	0		
							House rat	52	0	0		
Issyk-Kul' region	284	1944–1952	Fox	36	2	-	-	-	-	-	-	-

1	2	3	4	5	6	7	8	9	10	11	12	13
Issyk-Kul' region	285	1955–1957	–	–	–	–	Mole rats	+	+	+	–	–
Oshsk region	289	1955	–	–	–	–	Red-tailed desert vole	166	0	0	–	–
							House rat	258	0	0		
							Hamster	43	0	0		
							Turkish rat	22	0	0		
							Lesser Jerboa	13	0	0		
Frunze and Tien-Shan regions	289	1946–1958	–	–	–	–	–	–	–	–	16	–
Frunze and Talassk regions	285	1955–1959	–	–	–	–	Narrow-headed vole	+	+	+	–	–
East Siberia and the Far-East												
Krasnoyarsk Krai	275	1945–1959	–	–	–	–	–	–	–	–	98	–
Krasnoyarsk Krai (mostly southern districts, but also Taimyr and Zvenkiisk national districts)	334	1949–1964	–	–	–	–	–	–	–	–	237	–
Krasnoyarsk Krai	278	1955–1959	–	–	–	–	–	–	–	–	43	–
Krasnoyarsk Krai (Taimyr peninsula, northwest district)	404	–	Fox	+	+	+	–	–	–	–	–	–

1	2	3	4	5	6	7	8	9	10	11	12	13
Krasnoyarsk Krai (Turukhansk and its neighborhood)	76	-	Polar fox	50	20	40	*Microtus oeconomus*	7	3	-	8	-
			Dog	33	1	-						
Krasnoyarsk Krai												
Taiga (Tesevsk, Baikitsk, Dzerzhinskii districts)			Fox	11	2	-	-	-	-	-	-	-
Forest-steppe (Kansk, N-Ingashsk, Ilinsk, Sukhobuzimsk, Emel'yanovsk, B. Murtinsk districts)	104, 306	1954-1957	Fox	57	33	61	-	-	-	-	-	-
Steppe (Uzhursk district)			Fox	16	10	63	-	-	-	-	-	-
Tuvin ASSR (Tandin, Tes-Khansk, Dzhun-Khemchik districts)	391	1957-1960	Fox	-	-	35	*Microtus oeconomus*	18	-	5.5	+	-
							Daurian tree rat	38	-	2.7		
Irkutsk region (Cheremkhovsk, Uzol'sk, Irkutsk districts, Arlak Imak)	376	1924-1931	-	-	-	-	-	-	-	-	21	-

1	2	3	4	5	6	7	8	9	10	11	12	13
Irkutsk region	301	1924-1944	-	-	-	-	-	-	-	-	30	-
Buryat ASSR, districts												
Kyakhtinsk			Fox	2	1	-	-	-	-	-	-	-
Mukhor-Shibirsk	338	1941-1949	Fox	11	8	-	-	-	-	-	-	-
Selenginsk			Fox	6	4	-	-	-	-	-	-	-
Inoginsk			Fox	22	3	-	-	-	-	-	-	-
Baikalo-Kudarinsk			Fox	1	1	-	-	-	-	-	-	-
Barguzinsk			Fox	9	9	-	-	-	-	-	-	-
Buryat ASSR	339	-	-	-	-	-	Long-tailed hauster	+	+	0.9		
							Hoofed desert vole	+	+	0.5		
Buryat ASSR	16	1947-1957	-	-	-	-	-	-	-	-	1	-
Yakutia ASSR												
Anabar, N-Kolyma, Mid-Kolyma districts	295	-	Polar fox	80	48	60	Ob'lemming	174	-	21	-	-
Central districts	295	-	-	-	-	-	Red vole	411	-	0.2	-	-
							Narrow-headed vole	47	-	23		
Yakutiya ASSR												
Amginsk and Megino-Kangalaska districts			Fox	7	2	-	-	-	-	-	-	-

1	2	3	4	5	6	7	8	9	10	11	12	13
Ordzhonikidze district	377	1953-1958	Dog	59	20	34	-	-	-	-	-	-
Namsk and Mid-Kolyma district			Polar fox	11	4	-	-	-	-	-	-	-
Yakutiya ASSR	53	1948-1955	-	-	-	-	-	-	-	-	-	1.3
Yakutiya ASSR	264	1950-1965	-	-	-	-	-	-	-	-	811	-
Yakutiya ASSR entire including districts			-									
Allaikhovsk			-	-	-	-	-	-	-	-	559	-
Amginsk			Dog	5	1	-	Field vole	30	0	0	18	-
V. Vilymisk			-	-	-	-	-	-	-	-	35	-
Vilynisk			-	-	-	-	-	-	-	-	68	-
Gornyi			Dog	12	5	-	-	-	-	-	7	-
Kobyaisk			Dog	28	18	-	*Microtus oeconomus*	80	3		14	-
							Narrow-headed vole	15	12	11		
							Bank vole	18	2			
							Water rat	36	1			
Henskii	113	-	-	-	-	-	-	-	-	-	6	-
Megino-Kagabsk	28		Dog	43	2	-	-	-	-	-	30	-
Namsk			Dog	20	1	-	-	-	-	-	25	-

1	2	3	4	5	6	7	8	9	10	11	12	13
Nyurbinsk			Dog	5	4	-	-	-	-	-	31	-
Olekminsk			-	-	-	-	-	-	-	-	26	-
Ordzhonikidze			Dog	73	21	29	-	-	-	-	31	-
Srednekolymsk			-	-	-	-	-	-	-	-	6	-
Suntarsk		-	-	-	-	-	-	-	-	-	23	-
Tattinsk			-	-	-	-	-	-	-	-	28	-
Ust-Aldensk			-	-	-	-	-	-	-	-	14	-
Ust-Yansk		1937-1960	Polar fox	15	8	-	-	-	-	-	0	-
Churapchinsk			Dog	3	0	0	-	-	-	-	65	-
Yakutsk		1954-1960	Dog	3	1	-	-	-	-	-	12	-
Yakutsk city		1958-1960	Dog	17	0	0	-	-	-	-	68	-
Remaining 14 districts (see list) with 0-1-3 cases in each		1948-1958 1949-1959	-	-	-	-	-	-	-	-	15	-
Location not known			-	-	-	-	-	-	-	-	32	-
Magadan region	311	1954-1967	-	-	-	-	-	-	-	-	102	-
Magadan region:												
Anadyr neighborhood	60	-	Polar fox	40	4	10	-	-	-	-	-	-
Markovo neighborhood	60	-	Polar fox	2	1	-	-	-	-	-	-	-
Enurmino neighborhood			Polar fox	32	11	-	-	-	-	-	-	-
			Fox	14	0	0	Long-tailed hauster	7	0	0	-	-

1	2	3	4	5	6	7	8	9	10	11	12	13
Magadan region												
Chukchi national district (Anadyr and Iul'tin tundras)	87	-	Polar fox	35	22	64						
Magadan region, districts:												
North-Evensk			-	-	-	-	-	-	-	-	4	-
Anadyr			-	-	-	-	-	-	-	-	12	-
Eastern-Tundra	50	1954-1962	-	-	-	-	-	-	-	-	4	-
Providenie		-	-	-	-	-	-	-	-	-	4	-
Chukchi National district			-	-	-	-	-	-	-	-	6	-
Kamchatka region:												
Komandor Islands	269	-	Polar fox	35	8	22	Red vole	-	+	+	-	-
							Microtus oeconomus	48	25	49		
Kamchatka region												
Bering and Karazinsk Islands	350	-	-	-	-	-	Red vole	113	52	46	-	-
Kamchatka region, districts:												
Elizavet					-	33	-	-	-	-	-	-

1	2	3	4	5	6	7	8	9	10	11	12	13
Milkovsk	59	-	Fox	52	-	33	-	-	-	-	-	-
Bystrinsk					-	26	-	-	-	-	-	-
Kamchatka region	408	1953-1963	-	-	-	-	-	-	-	-	114	-
Kamchatka region Karyask National district	330	1963-1964	-	-	-	-	-	-	-	-	43	-
Amurskaya region and Blagoveshchesk	16	-	-	-	-	-	-	-	-	-	0	-
Khabarovsk Krai	59	-	Fox	70	0	0	-	-	-	-	-	-
Khabarovski Krai	16	1957-1959	-	-	-	-	-	-	-	-	-	-
Sakhalin region (Southern part of the Sakhalin Islands)	350	-	-	-	-	-	Bank vole	78	2	2.5	-	-

Legend. "-" denotes the absence of corresponding data, "+" denotes positive results of investigations without the mention of numerical information, and "0" denotes negative results of investigation.

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GEOGRAPHICAL DISTRIBUTION OF ONCHOCERCIASIS IN THE COUNTRIES OF THE WORLD

M.P. Stradomskaya

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INTRODUCTION

Onchocerciasis (onkhotserkoz in Russian, onchocercosis in Latin, onchocercose in French, onchozerkose in German and oncocercosis in Spanish) is a severe, chronic infection affecting the skin, eyes and lymphatic system of man. The disease is commonly called volvulose and maladie de robles in French and enfermedad de robles in Spanish.

Onchocerciasis is widely distributed in the equatorial and sub-equatorial belts of Africa and Latin America. During the last few years a few isolated cases of a disease similar to onchocerciasis (the causative organism has not yet been precisely identified) have been diagnosed in the countries of Europe and the Arabian Peninsula.

At present the fragmentary data available on the spread of onchocerciasis throughout the world give an incomplete picture of the extent of the disease. According to the World Health Organization's expert committee report of 1962, about 20 million people were infected with onchocerciasis in the tropical zones of Africa and Latin America, of whom a little more than 60,000 lived in Latin America (Mexico, Guatemala and Venezuela). According to Choyce [54], in 1963 20 million people were affected by onchocerciasis in Africa and 200,000 people in Latin America. The second evaluation of the number of patients in Latin America is perhaps somewhat exaggerated.

Onchocerciasis is not usually lethal but it brings about acute debility and a sharp decrease in a man's working ability. Loss of sight is another factor that reduces his earning power.

According to the British Society for the Blind there are 250 blind to every 100,000 of the population in places where trachoma is endemic and 500 to every 100,000 in regions hyperendemic for onchocerciasis. The figure is sometimes as high as 1,500 or more [19].

Onchocerciasis is supposed to have originated from Africa. Many authors think that onchocerciasis was carried to Latin America in the 16th century [23, 45, 52, 77, 95, 192, 193, 236]. However, some are of the opinion that onchocerciasis was known in Central America earlier than this [54]. Onchocerciasis was reported for the first time in medical literature at the beginning of 1900 in Africa and Latin America.

Two conferences on onchocerciasis have been held in Africa; one in Leopoldville (now Kinshasa) in 1954 and one in Brazzaville in 1961; other scientific and consultative WHO groups have met to discuss the clinical aspects of the disease and entomological findings.

In Latin America (Guatemala) the first scientific paper to attract medical attention to the problem of onchocerciasis was published in 1930.

At the Tenth Pan-American Conference in Bogota in 1938 representatives of Mexico and Guatemala drew the attention of the scientists present there to onchocerciasis as being an important medical problem in their countries. There was acknowledgement of the necessity of taking collaborative steps to evolve methods of treatment and prevention of onchocerciasis. In 1943, at the Pan-American Conference in Mexico, opinions were exchanged on the importance and magnitude of this problem in Latin American countries.

A plan of research, control and eradication of onchocerciasis in the Americas was drawn up. Great attention was paid to this problem at the second Pan-American Conference held in Montevideo in 1945, at the Third Pan-American Conference of Ophthalmologists in Havana in 1948 and at the Fourth Conference on the Problems of Tropical Medicine in Washington in 1948. The first conference of WHO experts on the problems of onchocerciasis was held in Mexico in 1953. The problem was again discussed at the Tenth Pacific Conference in Honolulu in 1961.

The causative organism of onchocerciasis is the helminth onchocerca volvulus (Leuckart, 1893); class nematoda, family Filaridae, sub-family Onchocercinae (Leiper, 1911), of the genus Onchocerca (Diesing, 1841). The synonyms of the causative agent are as follows: Filaria volvulus (Leuckart, 1893); Onchocerca volvulus (Railliet and Henry, 1910); Microfilaria nuda (Rodenwalt, 1914) and Onchocerca caecutiens (Brampt, 1919) [235].

It was thought for a long time that onchocerciasis in Latin America was brought about by two different causative organisms of the genus Onchocerca (Diesing, 1841), namely O. volvulus (Leuckart, 1893) and O. caecutiens (Brumpt, 1919), [8, 11]. Many authors considered them as synonyms. At present it is thought that the causative organism of onchocerciasis in Africa as well as in Latin America is one species of the helminth Onchocerca volvulus (Leuckart, 1893), [23, 54, 90, 110, 193, 276]. The definitive host of O. volvulus is man. The question of the natural reservoir of O. volvulus has been insufficiently studied. Under natural conditions O. volvulus was found in monkeys (Ateles geoffroyi vellorosus) in Mexico in the states of Chiapas and Oaxaca and in gorillas in Congo, Kinshasa), [9, 193]. In the body of man the mature O. volvulus inhabits the connective or subcutaneous tissue where the reproductive stage of their development takes place. The larvae produced by the female helminth (microfilaria) remain in the superficial layers of the skin in a stabilized state. The intermediate host for the development of the larvae of O. vulvulus and the vectors of the disease is the blood-sucking black fly of the family Simulidae. In Africa and America onchocerciasis is transmitted by different flies of this family.

The question how man became infected by onchocerciasis remained unsolved for quite some time. The possibility that the black fly (simulium) might play a role in transmitting onchocerciasis to man was first indicated by the Guatemalan doctor, Robles, in 1915. Onchocerciasis obtained its second name of Robles disease because of him. While sucking blood from infected human beings the black fly (simulium) sucks large quantities of larvae of O. vulvulus with the blood. These then move to the thoracic muscles and then to the flying muscles. In a period of six to seven days they develop to a stage in which they can infect man. When the infected female attacks man the larvae of O. volvulus are injected into his body during the process of blood sucking. Mechanical transmission of infection by the black fly does not take place during the interrupted blood sucking on a sick man followed by attack on a healthy man.

The causative organism O. volvulus develops in the black fly to the invading stage only when the outside temperature is 21°C or more. In lower temperatures the larvae of the parasite do not develop to the invasion stage in the black fly and transmission does not take place. The temperature required for the development of the larvae of the parasite perhaps explains the reasons this disease is found only in equatorial and sub-equatorial belts.

Onchocerciasis cases registered in these belts could have been brought about by the causative organism of onchocerciasis being present in domestic animals (horses, cattle and camels). These are widely distributed throughout the world in different climatic belts and happen to be carriers [54]. In many regions of the world cattle are attacked by the genus onchocera (Diesing, 1841). The clinical manifestations of the disease in man and domestic animals are similar [54]. The intermediate hosts and vectors of the causative organism of onchocercosis in domestic animals are the blood-sucking simulidae. The causative organism of onchocerca in horses is O. cervicallis and O. reticulata; in cattle it is O. guttorosa, O. bovis, O. gibsoni, O. lienallis, O. armillata and in camels it is O. fasciata. However, the whole process is not clear and further research is necessary.

The black fly that is the vector of onchocerciasis breeds in rivers and the infection of man takes place only in regions near their breeding grounds.

The black fly is an important factor in the spread and epidemiology of the disease and much attention has been given to the ecology and epidemiological activity of this vector.

2. ONCHOCERCIASIS IN AFRICAN COUNTRIES

In Africa, onchocerciasis is to be found in Angola, on the shores of the Ivory Coast, Upper Volta, Gabon , Ghana, Republic of Guinea, Portuguese Guinea, Dahomey, Cameroon, Kenya, Congo (Brazzaville), Congo (Kinshasa), Liberia, Mali, Niger, Senegal, Sudan, Sirra Leone, Tanzania, Togo, Uganda, Central African Republic, Chad, Equatorial Guinea and Ethiopia. One case (the causative organism was not identified) was reported in 1926 in the city of Tunis. [24].

2.1. VECTORS OF ONCHOCERCIASIS

Two species of the black fly act as vectors of onchocerciasis in Africa: *Simulium damnosum* (Theobalt, 1903) and *Simulium neavei* (Roubaud, 1915), also *S. renauxi* (Wanson, 1950). The role of the black fly *S. damnosum* as vector of onchocerciasis was determined by Blacklock in 1926 in Sierra Leone and the role of the black fly *S. neavei* was determined by Isett in 1932 in the Congo (Kinshasa).

The black fly, *S. damnosum* is the more widespread. It is found in tropical rain forests, in deciduous forests, in moderately humid, evergreen forests, in the tall grass and desert savanna, in scrubland where the shrubs are without leaves in the dry period of the year, in the interzonal valleys of the Nile and in the desert. (Fig. I, Appendix). However, in the typical and the desert savanna of West Africa, the park savannas of Angola and Tanzania and the scrublands of Ethiopia which have a prolonged dry period of six to nine months the black fly *S. damnosum* is seen only in the humid season and disappears completely in the dry part of the year.

The black fly *S. damnosum* is to be found up to 1,800 meters above sea level but is abundant in regions up to 1,000 meters above sea level.

It is rarely seen in the hilly regions and on the high plateaus of East Africa.

In West Africa and also in Sudan and Ethiopia, S. damnosum is the only vector of onchocerciasis and in Central Africa it is the main vector of this infection.

The distribution of the second vector, S. neavei, is rather restricted and it has different altitude parameters (800 meters, rarely from 500 to 2,100 meters above sea level). It lives on the high plateaus of Uganda, Kenya and Congo (Kinshasa) and in the interzonal forests and tall grass savanna. (Fig. 1).

The larvae of the black flies S. damnosum and S. neavei develop in fast-flowing and well-aerated rivers. The imago complete its cycle of development in the air.

2.1.1. ECOLOGY OF THE VECTOR SIMULIUM DAMNOSUM

2.1.1.1. THE LARVAL STAGE

In its aquatic stage of development, S. damnosum requires certain conditions. The water should have a high oxygen content and should be swift-flowing. There should be places of anchorage at depths not below 15 cm. from the surface and plentiful supplies of food.

The physico-chemical composition of the water (acidity, alkalinity, turbidity) are of secondary importance.

One of the main conditions for the development of a larval colony of the black fly S. damnosum is high oxygen content of the water. For depositing eggs they always select places on rivers with strong whirlpools or waterfalls where the high oxygen content of the water is the result of intense turbulence. The speed of the current of a river, which is related to the quantity of oxygen dissolved, should not be less than 50 cm./second for the black fly S. damnosum [117, 175]. The maximum speed of the current of a river in which larvae can become attached to the substrata is 200 to 250 cm./second [166].

In its breeding grounds in Central Africa the speed of the river current varies from 84 cm./second to 196 cm./second; in West Africa it varies from 70 cm./second to 120 cm./second [119, 282].

The black fly's selection of places for egg deposition in regions where there are rapids, whirlpools and waterfalls is explained further by the fact that in Africa there is higher humidity in these regions, which is required for the growth of the imago. This is important for the zones of dry savanna where humidity is low.

The presence of congenial substrata in the river suitable for egg deposition is also important. On the plains of West and Central Africa, the black fly S. damnosum mainly lays its eggs on water plants which in addition provide their larvae and nymphs with oxygen given out during the process of photosynthesis [119, 282].

In the hill rivers the main substrata for the egg deposition of S. damnosum are large boulders and half-submerged branches of trees.

The larvae of S. damnosum feed on microscopic water plants and organic waste. The following kinds of water plants have been found in the intestines of the larvae of these black flies in Centra Africa: ulothrix, cladophora, vaucheria, conferva, scenesdesmus, chalamydomonas, euglena [112, 282]. The pupae of the black fly do not feed.

A dearth of feeding material in a river can limit the places of anchorage for the larvae and has a bearing on the speed of current required for the species to thrive.

The surface temperature of the water throughout the year in the endemic regions of Africa is not a limiting factor. In low-altitude regions of Central Africa where there is no significant seasonal or daily variation in temperature (23.5° to 24°C) the growth of the larvae takes five days and of the nymphs four days: the whole cycle of development from egg to mature insect takes nine days [282].

In West Africa, where the average water temperature is 21° to 22°C, the larvae of S. damnosum grows in 10 to 13 days on an average and the nymphs in four days: the whole cycle of aquatic development takes 14 to 17 days [166].

In the hilly areas of Central Africa the larvae and nymphs of S. damnosum have been found at a height of 1,410 meters in the river Ruzizi and its tributaries where the water temperature was 15°C [105].

2.1.1.2. THE IMAGO STAGE

The mature winged insects emerge at sunrise and usually take flight en masse.

Immediately after emergence copulation takes place between the insects. Then the impregnated female flies off in search of suitable feeding grounds.

One full meal of blood is sufficient for gestation to commence. The females of S. damnosum are not strictly anthrophilic for they attack domestic animals as well as man and, rarely, birds or wild animals. The female S. damnosum usually has her first meal on the day of emergence or the following day. They fly great distances to find suitable feeding and usually follow the paths taken by people leading their cattle to grazing. The number of S. damnosum females in flight decreases by 24% for each kilometer flown from the breeding ground [9].

In the tropical rain forests of West Africa, in the basin of the River Bandamy, 1800 females were found near their breeding place on a particular day. At 20 kms. from the breeding place, 416 females were found; 35 kilometers away there were 85 females and 41 kms. away only 16 females were left [166].

The flight of the females and their distribution over an area depends on wind, humidity, cloud formation and vegetataion. A light wind with a velocity of 0.2 to 0.3 meters/second or windless weather helps the flight of the females. A wind with a speed of one to four meters/second creates strong resistance for the black fly. When the wind has a speed of 5 to 10 meters/second S. damnosum is immobilized. In such weather conditions they remain close to their breeding places clinging to trees and other vegetation [282].

The black fly S. damnosum prefers cloudy weather with high humidity and avoids high temperatures and bright light.

Relatively high humidity is favorable for the distribution of the black fly over a territory and for extending the duration of the flight.

In the rainy season when the weather is humid and cloudy the females spread out in all directions and fly considerable distances from their breeding grounds. During this season, in open, unforested areas, the female *S. damnosum* can be found at all points of the radial. In dry weather the female *S. damnosum* keeps to the protective cover of vegetation, which forms a very good micro-climate for them (linear distribution). In forest areas the black fly is widely distributed. In the savanna breeding and migration is only possible where there is vegetation along the river banks.

During dissemination the black fly is very particular about the kind of vegetation it alights on. In West Africa, along the Black Volta river, the black fly *S. damnosum* selects the following vegetation to rest on: *Mimosa asparata*, *Syzgium* sp, *Pteracartus* sp, *Morelia* sp [135]; along the White Volta and Red Volta rivers it selects *Acacia pennata*, *Mimosa asparata*, *Mytragina inermis*, *Fromager*, *Cailcedrat* and others [235].

In northern Nigeria the black fly *S. damnosum* is more frequently found on *Adina microcephala*, *Vitex domina*, *Khaya*, *Semgalensis*, *Isoberlina* sp, *Butyrospermum parkaii* and *Salix ledermanni* [61].

Coffee plantations also offer ideal conditions for the dissemination of the black fly.

In Central Africa the black fly most frequently takes shelter under blades of grass (*Paspalum notatum*) to protect itself from the heat of the day.

The changes wrought by man in the landscape can have a great influence on the distribution of this vector. Reduction in vegetation by the felling of forests for laying roads or establishing plantations restricts the distribution of the female. On the other hand land cultivation and the planting of forest corridors in the savanna facilitates the spread of the black fly.

After it has sucked its fill of blood, the female begins to look for places favorable for completion of the first gonotrophic cycle. If the females take flight in a radial way from their breeding ground they find it difficult to return. They find it easier if the flight is linear.

While the eggs are maturing the females are less mobile. They attach themselves to the thick leaves and lower branches of trees and other vegetation on the banks of rivers. In Central Africa the plants they most frequently attach themselves to are Uapaca guineensis and Vafia bossenge which hang less than one meter above fast-flowing water. The eggs mature 96 hours after the female S. damnosum has had her first meal of blood.

The outside temperature has a bearing on the development of eggs in the ovaries of the female S. damnosum and on the whole gonotrophic cycle. The higher the temperature, the quicker the eggs mature. In forest areas where the temperature is 27°C the first egg deposition of the black fly takes place 70 hours after the first meal but in the tall grass savanna where the temperature is 22° to 23°C laying begins after 90 hours [166]. Under favorable conditions, when egg deposition is complete the S. damnosum female begins to search for a source for her next meal. Though they are as aggressive and as bold as they were before the first feeding they do not fly great distances the second time but concentrate their quest for food within their new habitat. Here they undergo the second and third gonotrophic cycles. They do not cover great distances after this, particularly those females in which O. vulvulus is developing.

2.1.1.3. ABILITY OF THE BLACK FLY SIMULIUM DAMNOSUM TO WITHSTAND UNFAVORABLE DRY WEATHER (PERIOD OF ESTIVATION)

In regions where the dry season lasts for six to nine months the drying up of the rivers leads to the drying up of the breeding places in them and to the subsequent death of the S. damnosum larvae. For a few months there are no mature insects at all. How and in what stage the black fly withstands this summer period is of great practical interest.

There are two opinions about this. One is that the larvae and imago remain in the same place and in the same stage of development throughout the dry season in a state of estivation. The other is that the imago flies off to a point far from the breeding ground. The first opinion assumes that there is a stable, pre-imago phase (eggs, larvae and nymphs) which can withstand the dry season in a state of diapause. Eggs of many species of Simulium in Europe and the United States of America can withstand the drying up of water for quite some time (56 to 160 days) and are able to survive in stagnant water ⌊160⌋. Very little information is available for the African species. From observations of the eggs of S. damnosum in Ghana it appears that the possibility of the eggs surviving the dry season in this way is remote. Attempts were made to find eggs of S. damnosum that might have withstood the dry season in a state of diapause in the River Buguriba ⌊35⌋ but a thorough search of the dried-up breeding grounds yielded only three small colonies of shriveled eggs which were in a very bad condition. After heavy rain and the subsequent reappearance of water the dry substrata were found to be covered with fresh S. damnosum eggs though not one had developed further. The authors came to the conclusion that the assumption that eggs of S. damnosum survive the dry season in a state of diapause is implausible [160]. Eggs of S. damnosum were not found either in the ponds that had survived the dry season [160]. It was therefore not possible to prove that the biotype survives through larvae being hatched from eggs that have withstood the drought in the dry substrata or in the damp earth under the riverbed.

The presumption that larvae of S. damnosum withstand the dry season in a state of diapause has not been proved either.

The larvae of S. damnosum can live only for a very short time in the small pools of stagnant water left behind in the dry season, which makes it improbable that they can survive in a state of dispause through the months of drought [119, 160].

The way the nymph of simulidae withstands the dry season when it has to remain out of water has been inadequately researched. That nymphs can adjust to life out of water as a result of a sharp decrease in the level is known of the Paleariatic species, which can hatch even after remaining out of water for several days. In respect of the African species such adaptation to the unfavorable conditions of prolonged drought is not known. It has been presumed that the nymphs of S. damnosum can withstand the dry season for some months in stagnant water; however, so far it has not been possible to observe them under these conditions [59, 160].

There is an opinion that the mature insect may be able to withstand unfavorable weather by remaining in a stage of diapause in as as yet undiscovered underground hiding place where the air is humid and the temperature relatively low, such as in tunnels made by rats, etc. [35, 59, 175].

According to the migration hypothesis, the females of S. damnosum do not stay where it has become hot and dry but migrate to more humid regions.

The reappearance of S. damnosum in their permanent habitat in the river when the drought is over occurs, according to this hypothesis, by their gradual movement from the lower reaches of the river to the higher reaches aided by the increase in the volume of water and humidity of the air. However, how the black fly really withstands the dry season is yet to be discovered.

2.1.2. ECOLOGY OF THE VECTOR SIMULIUM NEAVEI

2.1.2.1. THE LARVAL STAGE

The black fly S. neavei has not been completely researched. Nothing is definitely known about the location of the breeding grounds and what the process of egg deposition is. For a long time nothing was known of the larval stages of the insect though much detailed research had been done on it.

Only in 1950, in Kenya, was a phoretic relationship established between the larvae and nymphs of S. neavei and the freshwater crabs that live in fast flowing streams and rivers that never dry up [115]. It was suggested that the female S. neavei deposits her eggs on the vegetation growing on the banks near the cascades and waterfalls where the crabs live [115]. However, this has not yet been proved. It is presumed that the larvae of *S. neavei*, in a rather early stage of growth, live freely in water and can migrate and that it is only in the mature stage that they fasten onto the crabs. The factor governing the symbiosis of *S. neavei* larvae with crabs is their need for oxygen and food. In the Congo, freshwater crabs carrying larvae and nymphs of *S. neavei* were found in small mountain streams having currents with a speed of 98 to 196 cm/second [86]. The larvae feed on the food left over by the crabs.

In *S. neavei* larval stage continues to 22-32 days and the nymphs develop in eight to nine days. In the mountain streams of Uganda with a water temperature of 17.5° to 20.5 C° the whole cycle of development from egg to mature insect takes from 30 to 41 days [238].

Symbiosis of the larvae and nymphs of the black fly *S. neavei* has been observed with different species of freshwater crab. In the Congo (Kinshasa), in the basin of the River Kasai and its tributaries, the black fly develops symbiosis with the crab *Potamon (Potamonautes) luebensis*; in the upper reaches of the River Ituri with the crab *P. dybowskii* and the River Kibali with the crab *P. farandjensis* Rath [86, 97]. In Angola the larvae and nymphs of *S. neavei* were found on the crab *P. depressus* [86]. In Kenya, in its larval stages, *S. neavei* is a partner of the crab *P. niloticus* [198, 199, 200]. In the low-lying regions of Uganda the crabs *P. niloticus* and *P. granviki* develop symbiosis with *S. neavei* and in high-altitude regions it is the crabs *P. johnston* and *P. loveni* that do so [29].

In the course of research at Lake Albert larvae and nymphs of the black fly *S. neavei* were found on 50% of the crabs [29]. It has been proved that the larvae and nymphs of *S. neavei* are carried only by crabs whose pincers are more than 2 cm in diameter [86].

The larvae of *S. neavei* attach themselves to the areas around the mouth and between the eyes of the crab, to the gills and to the base of the claws and the nymphs attach themselves to the edges of the dorsal pincers [199, 200].

On any crab there are usually one to three, though occasionally as many as 10 larvae and one, two or three nymphs [86, 282]. It was thought that this happens because the females of *S. neavei* do not deposit eggs directly on the crabs [115]. According to other reports, in Uganda an average of 25 to 36 larvae and nine nymphs have been collected [29] from each crab.

2.1.2.2. THE IMAGO STAGE

The ecology and biology of mature black fly *S. neavei* have also not been fully researched. *S. neavei* are to be found in gallery forests and scrublands and are rarely found in places receiving little or no sunlight. The female does not fly great distances from her habitat even in the humid season and has a limited range. It is an anthropophilic species but may feed on birds and mammals.

2.2. SIMULIDAE AS VECTORS OF ONCHOCERCIASIS

Many biological peculiarities of the female vectors have a bearing on the epidemiology of onchocerciasis: the nature of their distribution in a given territory, their life-span, the number of gonotrophic cycles they complete and their infectivity.

The way the female vectors spread over a territory determines the degree of contact with man. They fly considerable distances from their breeding grounds to find a host (from 15 to 85 km) [9, 224]. In West Africa the female S. damnosum usually flies from 25 to 45 km from the breeding ground and in Central Africa 15 to 35 km [35, 282]. The distance the females fly and the way they are distributed depends on the natural conditions.

In areas where there are tropical rain forests the black fly flies out great distances from the breeding ground in search of a suitable host to feed on and a place to deposit her eggs. If the females are widely dispersed throughout a territory their contact with man is reduced but since a larger territory is covered it promotes wide distribution of the disease.

In the typical park and desert savanna zones where the trees and bushes lose their leaves in the dry season the female S. damnosum, which finds such conditions unfavorable, shows linear distribution from the breeding place under the cover of trees lining the river banks and is found not more than 700 to 800 meters from the place of breeding [166].

In the regions where this kind of linear distribution takes place the female vectors are confined to areas near the breeding grounds, which increases the degree of contact with man, particularly in the dry season when the inhabitants are concentrated around the water resources [166]. Along the perennial rivers in these regions there is close contact between vector and man throughout the year, which facilitates the most intensive spread of onchocerciasis in Africa.

In the park-like, deciduous and sometimes humid and evergreen forests and in the tall grass savanna zones the female S. damnosum disperses in two ways. In the rainy season they disperse radially and there is less contact with man; in the dry season they disperse linearly and there is closer contact. The female S. neavei differs from the female S. damnosum in that she does not fly great distances from her breeding ground even in the rainy season and has a limited flying range (640 to 700 meters from the river and maximum 29 km) [945]. They disperse in a linear way along rivers under the protective cover of vegetation.

The transmission of infection is possibly connected with the life-span of the female. The life-span of the female S. damnosum in Central Africa (Congo, Kinshasa) does not exceed 15 to 18 days [282]. In West Africa it is slightly longer: 23 days and maximum 28 to 30 days [166].

It increases with the transition from the tropical rain forest zone to the dry savanna and is longer in the drought than in the humid season. The life expectancy of the black fly in durations of seven days after their first blood sucking is calculated as 0.040; in the park-like deciduous forests, seasonally humid evergreen forest zones and tall grass savanna it is 0.380; in the more humid parts of the typical and park savanna it is 0.520 [166].

The year-around unfavorable conditions of the dry savanna and the dry season in the humid savanna have a restrictive influence on the distribution of females in these territories. The shorter flights of the females allow their food reserves to be utilized slowly, which contributes to the prolongation of their lives. [166].

The shortened life-span of the black fly in the tropical rain forest zones, where the excessive humidity and low population density make contact between vector and man infrequent and where the dense vegetation also makes contact with wild animals difficult, has a bearing on the transmission of the infection [179]. As a result, in the forest zones of Africa a high percentage of weak female S. damnosum is observed, which in turn leads to a shorter life-span [178, 179].

The limited life-span of the female S. damnosum in the tropical rain forest zones accounts for the fact that only very few (seven of 1,000 infected females) reach an epidemiologically dangerous age and become vectors of onchocerciasis [10].

In the park-like, deciduous, seasonally humid and evergreen forests and in the tall grass savanna, 250 of 1,000 infected females become vectors. This change of zone from tropical forest to savanna increases the ability of S. damnosum to infect the population 50 times [10].

The belt where the life-span of the female S. damnosum is longest comprises the more humid parts of the typical and park savanna (Sudan). These are hyperendemic regions for onchocerciasis. In this zone and in the dry season in the park-like, deciduous and seasonally humid and evergreen forest zones and in the tall grass savanna the chances of man becoming infected by onchocerciasis are many times more than they are all through the year in the tropical rain forests and in the humid season in the park-like deciduous forest and the tall grass savanna zones.

In the drier parts of the typical and park savanna, in the desert savanna and in scrubland where the trees lose their leaves in the dry season, the life-span of S. damnosum is not long and as a result its infecting capacity is insignificant, being more or less the same as that in the forest zone.

The life-span of the female S. neavei is approximately 60 days [45]. Its epidemiological activity is more than that of S. damnosum. The life-span of the females is dependent upon the number of gonotrophic cycles completed by them. In the tropical rain forest zones in West Africa females of S. damnosum usually complete one gonotrophic cycle and rarely two [166].

In the park-like, deciduous and evergreen and seasonally humid forest zones and tall grass savanna of the Congo (Kinshasa) the black fly S. neavei completes two or three gonotrophic cycles and in the more humid parts of the typical savanna of West Africa they complete four to five gonotrophic cycles [166, 178, 282]. In the drier parts of the typical and park savanna, desert savanna and scrubland, due to their shorter life-span, the females of S. damnosum complete one or rarely two gonotrophic cycles as in the humid, tropical forest zones.

The first gonotrophic cycle of the female S. damnosum usually ends on the fourth day. All the following cycles end on the sixth day [166, 282]. There is no variation in the duration of the gonotrophic cycles for the different natural zones [166].

The number of gonotrophic cycles the female S. neavei completes has not been established.

The more gonotrophic cycles the female vector completes, the higher the epidemiological activity and the greater the possibility of its infecting man. Because the gonotrophic cycle of the female S. damnosum continues for four to six days and the development of O. vulvulus to the invading stage takes six to seven days or more, the black fly as a rule does not transmit the infectious larvae during the first two blood suckings. It sometimes happens during the second but it usually occurs during the third and subsequent blood suckings. As a result the longer the life-span of the females vector (or when their average age is higher), the greater the possibilities of the causative agent of onchocerciasis being transmitted to man.

2.2.1. THE NATURAL INFECTIVITY OF THE FEMALE VECTOR

In Africa, considerable numbers of this vector are infected with *O. vulvulus*. In one blood-sucking of an infected man the female vector sucks in a large quantity of microfilaria (1,000 or more) [164]. However, only a small proportion reaches the infective stage in the vector.

Some of the *O. vulvulus* larvae that develop to the invading stage leave the female when she feeds on nectar which she does before her blood sucking. This decreases the infecting ability of the black fly and limits the possibility of transmission of *O. vulvulus* [74, 166, 282].

A larger number of black flies in a given zone become infected in the dry season than in the wet season.

No method of measuring the indices of the natural infectivity of the vector has yet been completely developed. There are likely to be considerable variations in the indices due to the different methods followed in dissecting females. Most authors do not mention at which stage the microfilaria were when examined to ascertain the degree of infectivity [235]. However, there are data showing beyond doubt that the differences depend on where the black flies were found, their numbers, the season of the year, their average age, etc. The infective ability of the female in each case varies from 2% to 30% [9].

In the Congo (Kinshasa) the average infectivity of the female *S. damnosum* in the basin of the River Uele is 7.3% to 18% [31]. In the region of the lower reaches of the River Congo, the average infectivity of the female *S. damnosum* in the dry season is 20.4% and the number of females with infectious larvae is 3.9%. In the rainy season, in the same area, the average infectivity of the female decreases to 15.3% [282]. In the Congo (Brazzaville), the average infectivity of the female is estimated to be 8.14% and the number of females with infectious larvae is 3.7%. In West Africa, in the basin of the Black Volta River, these figures are 18.5% and 2.8% respectively [135]. In Sudan the percentage of females with infectious larvae is 8.5% [175].

The natural infectivity of female *S. neavei* is higher than it is for *S. damnosum*. The average infectivity of *S. neavei* in the region of Sankuru Lubilash in the Congo (Kinshasa) goes as high as 33.3% [86]. In Kenya it is 25% and in Uganda it is 14% [235].

The infectivity of the female *S. damnosum* is inversely proportional to the distance from the place of breeding. Wanson, Henrard and Peel [286] observed in 1945 that near the banks of the River Congo (Congo, Kinshasa), the average infectivity of the female *S. damnosum* was 15.3%. This decreased sharply to 9% as they withdrew from the river banks. In areas two to three km from the river banks it was 3% to 4%, at four to eight and 12 km it was 1.9%. At distances of more than 12 km from the river the infectivity of vector dropped to zero.

Table 1. Infection of the female S. damnosum in the Congo (Kinshasa) in 1950 [282]

Place of collection (distance from the river, in km)	Number of females S. damnosum	Total % of infected female S. damnosum	% females with sausage-shape larvae	% females with infective larvae
1 - 6	1047	11.8	7.9	3.9
10	706	3.9	2.4	1.5
12 - 30	1383	0	0	0

The complete absence of infectivity in the female S. damnosum at a distance of more than 12 km. from the breeding place is explained by Wanson [282] as due to the parasite O. vulvulus being localized in the flying muscles of the black fly. O. vulvulus larvae enter into the muscle fibers causing rupture and necrosis of muscle fibers. This restricts the flying capacity of the infected females so that the zone in danger of becoming infected with onchocerciasis is limited.

Parallel observations are supplied by Kirk [147] and Lebrum [169], who found no infected females of S. damnosum at a distance of more than 13 km from the nearest breeding place. They found that in West Africa, in the park-like deciduous and evergreen and seasonally humid forests and in the tall grass savanna the maximum distance infected females fly is 19 km. In the tropical rain forest zones it is 17 km from the breeding place [166].

2.3. THE WAY THE FEMALE VECTOR ATTACKS AND INFECTS MAN WITH ONCHOCERCIASIS

The following factors govern the attack of S. damnosum: barometrical pressure, temperature, humidity of the air, light and wind. The lowering of barometrical pressure always activates attacks by the black fly. They are particularly active in the calm before a storm. They are not hindered by cold rain unless it is very heavy and accompanied by strong winds [166].

The lower and upper temperature limits for the activation of the black fly S. damnosum vary according to their physiological state.

The sterile female S. damnosum in West Africa is capable of attacking man at temperatures of 18°C and even lower. Fertile females which are potential vectors attack mainly in the second half of the day when the air temperature is rather high [166]. The optimum air temperature for an attack is 22° to 24°C [282].

The black fly usually attacks man in the cooler parts of the day, i.e. from six to eight in the morning and from four to six in the evening [235, 282].

Egg-laying females relapse into a state of torpor when the temperature is 36°C to 37°C. They cease attacking and take shelter in nooks and crannies (clefts of rocks and trees, etc.) until the temperature drops.

Non-laying females are sometimes observed even at temperatures of 40°C and higher [166].

The optimum humidity of the air for the female S. damnosum to attack is 65% to 85%. When the humidity is less than 55% activity ceases.

The black fly S. damnosum is active only during daylight. However, there have been reports of their attacking man on moonlit nights /‾135_/.

A calm, windless atmosphere is the most favorable. Strong winds reduce the strength of the attack.

S. damnosum sucks for one and one-half to five minutes and causes intense irritation which lasts for some time. Reaction to the bite of the black fly is very strong because its saliva has high toxicity, particularly in the dry months. A pin point hemorrhage appears after the bite and edema develops at the site. Blisters with serous contents appear. These usually turn into pustules with further inflammation of the skin and the formation of scabs. The inflammation and irritation of the skin continue for a week. When a number of such bites are inflicted the body temperature rises and general debility ensues.

In Sudan, S. damnosum has been known to inflict 200 bites on one man in one hour. On the banks of Goto, on River Maio..Kebbi (Republic of Chad), more than 400 bites are known to have been inflicted on one man in an hour. In the main areas of onchocerciasis in West Africa 500 bites in an hour have been recorded and in the eastern part of Kinshasa (Congo, Kinshasa), more than 600 bites /‾177, 264, 282_/. S. damnosum attack up to a height of one meter from the ground. In West Africa 96.9% of all the bites of S. damnosum occur on the feet or below the knees /‾235_/.

The behavior of the female S. neavei at the time of attack on man differs from that of S. damnosum. In the Congo (Kinshasa) in the Kisangani region, which is at a height of 480 to 500 meters above sea level, the female S. neavei bites man mainly on the lower part of the body but less frequently than S. damnosum. In the area of Sankuru.....Lubilash, which is situated at a height of 800 meters above sea level, S. neavei attacks mainly on the upper part of the body (head and shoulders) [86]. In regions situated above 1,000 meters above sea level S. neavei bites man mainly on the face [282].

In Kenya, in the area of Kodera, S. neavei has been known to inflict 200 bites on one man in one hour.

In Africa the inhabitants of villages and cities near the breeding grounds of S. damnosum are attacked. But the female S. damnosum is never found in covered places, even in houses very near the breeding ground.

The black flies sometimes attack man on shady verandahs, thus affecting mainly elderly folk. Menfolk in particular are affected by onchocerciasis due to their occupations, such as fishing, hunting, plantation work and lumbering.

Just as the infectivity of the female S. damnosum is inversely proportional to the distance from the breeding ground of the vectors so is the incidence of onchocerciasis among the population. In the onchocerciasis ridden areas near the confluence of the rivers Kvilu, Kvango and Inziei in the Congo (Kinshasa) the incidence among the adult population of the villages situated on the banks of the rivers near the breeding ground of S. damnosum was found to be 50% (of 135 cases examined). In villages three to 10 km away from the river this came down to 24%. In villages 15 to 20 km away, of 95 local inhabitants examined none had been infected.

Also proportional to the distance from the breeding ground is the severity of the eye infections among those attacked. In Upper Volta, in villages situated near the breeding grounds of the black fly, 10% of the total number of inhabitants and 15% of those over 15 years of age were found to be blind; 25% of the total number examined and 40% of those over 15 years of age had severe eye infections (sclerotic keratitis), irridocyclitis, chorioretinitis) which to a greater or less extent affected their vision.

In villages far from the breeding grounds of this vector the percentage of blind among the people examined was rarely more than 2%. In villages still farther away the percentage of blind was zero. This, in spite of the fact that among those examined the incidence of onchocerciasis sometimes reached 50% [251].

2.3.1. CLINICAL FEATURES OF THE DISEASE

The most characteristic feature of onchocerciasis is the presence of subcutaneous, hard, mobile, very painful nodules ranging in size from a pin head to as big as a pigeon's or hen's egg. These nodules are isolated but frequently numerous, particularly in elderly folk.

In West Africa, one to 15 nodules are found in a single patient and a maximum of 35 to 40 (the vector is _S. damnosum_). In Central Africa, in the Congo (Kinshasa) in the province of Kasai, the intensity of infection is as high as 90 to 100 nodules on the average in a single patient and with a maximum of 126 (the vector is _S. neavei_) [131]. However, in Kenya, where _S. neavei_ is also the vector, in a single patient, only one or two, occasionally three to five nodules are found.

Most of the nodules (93.7%) are distributed on the pelvic girdle, feet and chest. They are rarely found on the higher parts of the body, on the head and shoulders.

Other clinical symptoms of onchocerciasis in Africa are various skin, lymphatic and eye infections. Among the skin infections the most characteristic are severe pruritis, xeroderma, pigmentary changes, specific dermatitis, atrophy and premature wrinkling of the skin. Among the infections of the lymphatic system the most characteristic are lymphadenitis, hydrocele, chyluria and elephantiasis.

Eye infections are the most serious complications of onchocerciasis. Many of them are incurable and are the cause of considerable impairment of vision and even blindness. The most characteristic eye infections with onchocercal etiology in Africa are punctate and sclerotic keratitis, irridocyclitis, pyriform deformation of the iris, chorioretinitis and atrophy of the optic nerve. In many regions of West and Central Africa infection of the eye with onchocercal etiology is found in 30% to 35% of the population and 4% to 10% of the population is blind. In the countries of West Africa there are 400,000 blind and onchocerciasis is the chief cause [19]. The highest percentage of blind is found among working males. The onset of blindness can occur as early as 10 years of age but below the age of six years the clinical symptoms of onchocerciasis hardly ever occur [282].

2.4 TERRITORIAL BOUNDARIES OF ONCHOCERCIASIS

The endemic territory of onchocerciasis is restricted to the distance the infected female vectors fly from the breeding ground, i.e. to a radius of 12 to 19 km. The almost permanent concentration of infected female vectors around the breeding place forms a permanent danger zone for the infection of man.

The area onchocerciasis covers is not compact but is formed of separate, isolated pockets. In the tropical rain forest zones with their dense river networks, which have numerous places suitable for the breeding of the vector, onchocerciasis is present in many pockets which are usually close to each other. Onchocerciasis can occur at almost any point of territories having typical and park savanna with few river networks. The areas of onchocerciasis are localized in these zones and are separated by wide, uninfected pockets.

Within the territorial boundaries of S. damnosum, onchocerciasis is found in places near big rivers rather than their tributaries. Within the territorial boundaries of S. neavei the places where onchocerciasis is found are near the tributaries of large rivers and mountain brooks and streams.

Because of the ecological peculiarities of the vectors, which vary according to the natural environments that suit them, onchocerciasis differs from pocket to pocket in the degree, intensity and season in which it attacks man as well as in its clinical symptoms.

2.5. KINDS OF AREAS WHERE ONCHOCERCIASIS IS FOUND

So far no hard and fast parameters as to the areas where onchocerciasis is typically found have been worked out. In this paper an attempt has been made to classify the places where onchocerciasis is found, taking as a guideline the ecology and socio-geographical peculiarities of the transmission of the causative agent.

The ecological characteristics of the female which determine the effectiveness of the transmission of the causative agent are the basis for classifying the locations. These are the life-span, the number of gonotrophic cycles they complete, the nature of their distribution over territories, (radial, linear or mixed) and the social factors governing man's contact with the black fly.

When distribution is linear the greatest contact with man occurs and transmission of onchocerciasis is intensive. When distribution is radial the contact of the fly with man is reduced and so are the chances of his being infected. When distribution is mixed, it is radial in the rainy season and linear in the dry season. Where distribution is linear the incidence of reinfection is high and the clinical symptoms are severe with serious eye infections and a high rate of blindness occurring as a result of onchocerciasis. Where distribution of the vector is radial the severe clinical forms of onchocerciasis are not found but skin and lymphatic infections predominate. The number of blind is insignificant in these areas.

The vector S. damnosum is to be found in four kinds of locations, the vector S. neavei in five. The degree of the endemic nature of the areas of onchocerciasis has been classified according to the classification adopted by WHO in 1966. They are hypoendemic, where less than 33% of the population is infected with microfilaria of the skin; mesoendemic, where 34% to 66% is infected and hyperendemic where more than 67% is infected. The percentage of carriers of subcutaneous onchocercal nodules corresponding to this classification is from 0% to 10.9%, 11% to 21.9% and more than 22% respectively [251].

2.5.1. THE DIFFERENT TYPES OF AREAS WHERE ONCHOCERCIASIS IS FOUND

TYPE I. VECTOR S. DAMNOSUM

These are the tropical rain forests in West and Central Africa. Such forests are found in the broad basin of the River Congo having nearby a watershed plateau and mountain ranges on the border of Gabon. The boundaries of the forests are 3° to 4° on either side of the equator (Fig. 2, appendix).

The territory is characterized by permanent high humidity and a uniformly high temperature. The annual rainfall is more than 1,500 to 1,700 mm. There is hardly any dry season or is weakly expressed. The humidity of the air is always high (80% to 100%). The average annual temperature is 25°C to 27°C and throughout the year it never goes below 24°C. The rivers have many branches, are permanently full and contain a great many rapids.

These tropical rain forests have a very wide variety of vegetation, almost untouched, with the exception of the selective cutting of the most valuable trees. Few animals are found. The sparsely scattered inhabitants (one to three men per square kilometer) are occupied in hunting, fishing and collecting the useful products of the forest.

Only in Nigeria has this picture of the tropical rain forest been changed. It is economically the most important area of the country and almost half the population is concentrated in it; large cities have sprung up. In the forest zone of Nigeria the density of the population is 100 to 400 per square kilometer in the western region and 200 to 400 in the eastern region. This is where the cocoa and oil palm plantations are minaly situated.

The natural conditions of the forest zone are favorable for the black fly throughout the year.

The dense river network of the forests facilitates the distribution of breeding places over almost the whole area, with an attendent high incidence of onchocerciasis. Practically the whole population is in danger of contracting the disease. However, the epidemiological activity of the female vectors and their natural infectivity are not high here because they have a rather short life-span. It is calculated that in all probability their life-span in durations of seven days after the first blood sucking is 0.040.

The female S. damnosum completes one or very occasionally two gonotrophic cycles. This is the reason only a small number (seven out of 1,000 attacking females) are vectors. The disease can be transmitted throughout the year.

In forest zones the distribution of the females is radial and remains the same throughout the year, promoting a wide distribution of onchocerciasis. Radial distribution of the females, despite their large numbers, leads to the thinning of their numbers and in the case of areas where the population is thin and sparsely scattered, with the exception of areas that have been reclaimed from the forest, the contact of the black fly with man is slight. This applies however, only to the larger territories.

This low rate of contact of the vector with man which excludes the possibility of reinfection and a small percentage of females reaching the epidemiologically dangerous age produce a rather low rate of transmission of onchocerciasis and low intensity and limited infection of the population. During his lifetime a man would be invaded by a relatively small number of infective larvae (an average of 0.72 infective larvae of *O. vulvulus* in a day and of 266 larvae in a year) [308]. Despite the fact that the entire population of this zone is in danger of being infected by onchocerciasis the intensity of infection is much lower than it is in the savanna zones. Due to the absence of reinfection severe clinical manifestations of the disease are hardly ever observed. Skin infections of onchocercal etiology are the most common symptoms. Subcutaneous onchocercal nodules are found in fewer than 10% of patients. Eye infections are rare. Sclerotic keratinization is never found and the incidence of punctate keratitis is much lower than it is in the savanna. Atrophy of the optic nerve is found very rarely. This explains the low incidence of blindness of onchocercal etiology among the local inhabitants of these zones. Eye infections are found in 0.08% to 2.1% and blindness in 0.4% to 1.6%. Among the clinical forms of the disease, lymphatic infections of onchocercal etiology are most commonly found (lymphadenitis, elephantiasis of the genitals, occasionally elephantiasis of the feet, chyluria, hydrocele). Onchocerciasis in the forest zones is usually hypoendemic. However, in the widely reclaimed regions it is sometimes mesoendemic or hyperendemic.

The risk of infection in this zone is much lower than in the savanna zone but covers a wider territory. The people do not leave the regions where the black fly population is high.

TYPE II. VECTOR *S. DAMNOSUM*

These are the park-like, deciduous and evergreen, seasonally humid forests and tall grass savanna of West and Central Africa (savanna of Guinea).

The yearly rainfall is from 1,200 to 1,700 mm. The humid season lasts eight to eleven months. The relative humidity of the air in this period is 80% to 95%. In the dry season the relative humidity of the air is rarely lower than 70%. The zone has a comparatively high temperature throughout the year. The average annual temperature is in the range 26° to 28°. The amplitudes of the average monthly temperatures are insignificant because in the days and months when the sun is right on the zenith the temperatures are brought down by considerable cloud.

There is a dense network of rivers, always full, usually with the stony river beds associated with the superficial or shallow occurrence of crystalline rocks of the African platform. The rivers have plenty of dams and waterfalls.

In this zone the humid, tall grass savanna, covered with a thick layer of grass having a height of one and one-half to four meters, and the deciduous and evergreen forests, less dense than the Gilie are landscapes of a park-like character. Along the banks of the rivers are evergreen forests.

The many-branched river network, heat and humidity favor mass breeding of the black fly and many other insects which are vectors of endemic infectious diseases. This makes it difficult to develop these territories for habitation. For this reason there is very little agricultural activity and animal husbandry is practically impossible because of the tsetse fly. The population density is low (0.7 to 4 men per square kilometer) in the valleys of the Senegal river and its branches (Mali). There are fewer than five men per square kilometer over large areas cultivated along the River Negros in the Republic of Guinea and on the middle reaches of the River Volta in Ghana and three to four men per square kilometer in Nigeria. This landscape zone is the least populated and least economically developed part of the African continent.

Onchocerciasis is usually found in pockets in this zone, not all over as in the forest zone. In the humid season, the black fly spreads radially and in the dry season linearly.

The environment is favorable for their development up to the invading stage. Transmission is possible throughout the year.

The epidemiological activity of the fly is higher than it is in the forest zone but lower than it is in the zone of typical savanna. The probable life-span of the female in durations of seven days after the first blood sucking has been calculated as 0.380. The female completes two or three gonotrophic cycles. Of 1,000 infected females, 220 reach the epidemiologically dangerous age and become vectors of onchocerciasis.

The vector is likely to come into contact with man over a fairly large territory but contact is reduced in the humid part of the year (during the radial spread of the female) and is frequent in the dry season (during linear distribution). Due to the thinning out of the flies during radial distribution in the humid season the intensity of transmission of the disease is lower; there is a decrease in the number of bites and hence in the number of infective bites. Reinfection is rare. The people who live within the area of radial distribution of the black fly come into contact with the vector only in the rainy season (eight to ten months of the year).

In the dry season when the relative humidity of the air is low, and there is no cloud the black fly is confined to a smaller area and the density increases. The black fly can only migrate in this period by following the rivers under the cover of the forest (linear distribution). Contact between man and black fly becomes very intensive and the danger of infection increases. The intensity of infection and number of infective bites being greater in this period reinfection occurs more frequently. Transmission of infection in the dry season increases many times. On an average a man in this zone will be invaded by 20.2 infected larvae of O. volvulus in a day, i.e. 7,432 in a year. In 20 days a man would probably be invaded by 400 infected larvae and run a 0.960 risk of infection /̄308_7. Where distribution of the black fly is linear, transmission of the disease is possible throughout the year. Where distribution is radial it can occur only in the rainy season. Severe clinical symptoms of the disease are common in areas where there is linear distribution as the number of infectious bites is greater and reinfection is common. Lagaulet and Amman /̄155_7 give clinical data collected from the basin of the Black Volta River. Where the distribution of the vector was radial the number of onchocercal patients was 70%; where distribution was linear it was 86% and the incidence of blindness was respectively 3% and 3.4%. Subcutaneous onchocercal nodules were found in 2.5% to 86% of the people examined. Eye infections (mainly punctate keratitis) were found in 2.1% to 21%, blindness in 0.4% to 6%, occasionally 10%, but hardly ever in more than 30% of the people examined. Infections of the lymphatic system were widespread; adenopathy, elephantiasis of the genitals, sometimes elephantiasis of the feet, chyluria and hydrocele. There were a large number of areas where the disease was mesoendemic and hyperendemic. The risk of man being infected is lower in the humid season and higher in the dry season. The population moves away from the valleys of the river when the risk is high.

TYPE III. VECTOR S. DAMNOSUM

These are the rather humid parts of the typical savanna of West Africa (savanna of Sudan) and the typical and park savanna of Angola (to the north of the River Kvanza).

These zones receive 800 to 1,200 mm. of rain a year. The main feature of the climate of these zones is the regularity of rainfall and the division of the year into humid and dry periods. The humid season lasts for six to eight months, when the relative humidity is 60%. The dry season lasts for four to six months with the relative humidity 40% to 45%. During the day it sometimes drops to 25% to 28%. Khamsin blows during the dry season.

The average annual temperature is from 28°C to 30°C. Considerable amplitude of temperature both yearly and daily are characteristic of these zones. The daily variation in the dry period of the year can be 25°C or even 35°C, which is explained by the small amount of cloud and relatively low humidity.

The river network is not so dense nor do the rivers always have water in them. Some rivers are periodically dry. Wadis are found but they dry up in the dry season.

This zone is permanently covered with thick, dense, tall grass (the height of the standing grass is 1.3 to 3 meters) with some isolated and some small clumps of trees. There are some islands of forest, mainly deciduous though sometimes evergreen and bushes all along the river banks. The vegetation stops growing in the dry season, the grass dries and the leaves of the trees fall.

The black fly lives in the valleys of perennially flowing rivers. They find a breeding place along these rivers throughout the year. Along rivers that are sometimes dry they find it in the rainy season only.

The black fly population is less dense in this zone than in the forest zone. Because of the low humidity, light fog, absence of cloud, very sparse vegetation cover and prolonged dry season, the flies hardly enter this territory, even in the rainy season. Hence the pockets of onchocerciasis are at considerable distance from one another and are separated by territories free from the vector. Onchocerciasis is occasionally observed beyond these locations but in places where conditions are favorable for the fly. A concentration of female vectors forms permanent hyperendemic areas and transmission of the disease is possible throughout the year.

The typical savanna of West Africa and the typical and park savanna of Angola are regions where land cultivation, animal husbandry and fisheries are economically quite well developed. This region resembles the savanna region of Guinea. Here, the basic commodities of arachis, cotton and sugarcane are grown in the river valleys. Rice is also grown and needs no artificial irrigation.

The most fertile and best grazing lands are in the river valleys where most of the population is concentrated. All this facilitates a very close and regular contact of man with the fly.

The epidemiological activity of the female vector in this zone is the greatest and the flies have the longest life-span. The probable life-span of the black fly in durations of seven days from the first blood sucking is estimated at 0.520. The females complete four to five gonotrophic cycles. A large number of females (350 per 1,000) reach the epidemiologically dangerous age and become vectors of onchocerciasis.

The black fly lives permanently in its breeding place and only very rarely is a linear distribution of the females observed along the river banks under the cover of vegetation. Of all the zones of Africa, the most intensive transmission of onchocerciasis takes place in this zone. Man is invaded by a number of infected larvae from early childhood and during his lifetime can expect to be invaded by 58 infected larvae of O.vulvulus a day; 14,184 in eight months of a calendar year is possible [308]. A man can be invaded by 400 larvae of O. vulvulus with a 0.960 risk of infection in seven days in this region. Multiple reinfection leads to severe forms of the disease.

The incidence of infection of the population by onchocerciasis is high. Subcutaneous onchocercal nodules are observed in 32% to 80% of those infected. Serious eye infections (sclerotic keratitis, irridocyclitis, chorioretinitis and particularly atrophy of the optic nerve) are found in 11.4% to 30% of patients. Blindness is found in 7% to 35% or more cases. The percentage of blind people in this zone is the largest in Africa. Infections of the lymphatic system (elephantiasis of the genitals) are not found as often here as they are in the two types of zones already described. There are many areas where the disease is hyperendemic. Many fertile river valleys (Banifing, Bangoe, Baoule in Mali, Kaio-Kebbi, Republic of Chad, etc.) have been deserted by the inhabitants and are hardly used for cultivation because of the presence of the black fly S. damnosum in large numbers and the danger of being infected by onchocerciasis.

Thus locations of type III are the most dangerous for infection of the population and the clinical symptoms of the disease are the most pronounced.

TYPE IV. VECTOR S. DAMNOSUM

These are the rather dry, northern parts of the typical and desert savanna of West Africa (Sakhel savanna) in the park savanna of Tanzania, in the scrublands of Ethiopia and Sudan, in areas where the trees are leafless during the dry season and in the desert zones. (There are some intrazonal areas in the valleys of the River Nile).

The annual rainfall is 500 to 600 mm. The humid season lasts for three to four months and the dry season for eight to nine months, during which period the black fly is absent. The average annual temperature is 28° to 30°C. There are sharp fluctuations in temperature in the course of 24 hours. There is almost no river network and almost no permanent source of water. Most rivers have water only in the rainy season. The grassy savanna becomes a savanna with acacia or other shrubs. The stunted vegetative cover is open and even thinner. It consists of flowering shrubs (various kinds of acacia, mimosa and others) and isolated not very tall trees which for the major part of the year are leafless, semiarid, thorny trees. Grass rarely grows as individual plants. The life-span of the vegetation in this zone is very short and most of the year the shrubs and trees are without leaves and the grass cover shrivels up.

As far as climatic and vegetation conditions are concerned, this landscape zone is transitional between desert to typical grassy savanna.

The natural conditions are unfavorable for the life of the black fly. The northern boundary of the distribution of _S. damnosum_ and onchocerciasis is at the latitude of 15° to 20° north. They are very few in number and active for only a short time of the year. Their scattered and isolated breeding places and the areas around them are separated by large territories free from the vector. Transmission of the disease along the rivers that continue to flow is possible throughout the year but along the ones that dry up it is possible only in the rainy season.

The natural conditions of this zone are also unfavorable to man's occupations. A thin river network makes for a low population density.

(0.7 to 3 men per square kilometer). The main occupation of the inhabitants of these zones is nomadic and semi-nomadic animal husbandry. Land cultivation is very limited and is only carried on when water is available. The population is concentrated almost entirely along the river banks and in the dry season these areas are practically deserted.

The epidemiological activity of the black fly in this zone is low. It is active only in the short rainy season; in the dry season it disappears completely. It completes one or two gonotrophic cycles and the natural infectivity of the females is low. The black fly in these zones is confined to isolated pockets and distribution, even linear, does not take place. The female vectors have close contact with a small number of people who permanently or temporarily (while plowing the land in preparation for the rainy season) live right in the heart of their habitat.

Their contact with man is rare; each man receives on an average a small number of infective bites. Reinfection is also rare. Transmission of onchocerciasis is seasonal and is possible only during a very short period of the year. The occurrence of the vector is too low to produce a high degree of infection among the people. Thus in these landscape zones of onchocerciasis, patients do not have severe clinical symptoms of the disease. Subcutaneous onchocercal nodules are found in 3% to 4% patients, eye infections in 7.7% to 10% patients, blindness in 1% to 2.3% and very occasionally in 10% of the cases examined. Infection of the lymphatic system (elephantiasis of the genitals) occurs very rarely. These areas are hypoendemic. Desertion of the fertile alluvial land where the vector breeds and flight of the inhabitants because of the danger of infection of onchocerciasis are unknown here.

TYPE V. VECTOR S. NEAVEI

These are in the park, deciduous and evergreen intermittently humid forests and the tall grass savanna on the plateau of Lunda in the Congo (Kinshasa), on the lake plateau of the West African hilly tracts and on the surrounding slopes in Uganda and Kenya.

The natural characteristics of these areas are similar to the natural characteristics of the areas of Type II (vector S. damnosum). They are classified in one landscape zone. The lake plateau surrounding Lake Victoria is characterized by high temperature and high humidity. The dry season here is not prolonged and in general not clearly defined.

The annual rainfall is on the average 1,500 mm. The temperature is steady at around 22°C to 24°C throughout the year.

The territory is very thickly populated (100 to 200 per square kilometer) and in some places there are as many as 400 people to a square kilometer. The main occupation of the inhabitants is agriculture.

The natural conditions are favorable for the survival of the black fly S. neavei throughout the year. The areas of distribution are numerous but isolated from each other because of the limited flight range of the black fly S. neavei. They are mainly found along mountain rivers and brooks.

The epidemiological activity of the female S. neavei and natural infectivity is high because of her long life-span. It has not been established as to how many gonotrophic cycles the female completes. Only linear distribution of the females throughout the year is observed. There is a very high rate of contact with man and hence intensity of transmission. People receive a large number of infective bites. Reinfection occurs many times. Transmission takes place throughout the year. In onchocerciasis patients in this endemic zone severe clinical manifestations of the disease are observed.

Subcutaneous onchocercal nodules (they are numerous in every patient) are found in 37% to 95% of the cases examined. Severe eye infections (sclerotic keratinization, irridocyclitis, chorioretinitis and atrophy of the optic nerve) are found in 37% to 43% of cases. Blindness is found in 4.7% to 20% of the cases examined. In respect of the severity of subcutaneous and optic manifestations of the disease, areas of type V resemble those of type III of the vector S. damnosum. Infection of the lymphatic system (elephantiasis of the genitals) is not found as often in these locations as in type II where the vector is S. damnosum. Most areas are mesoendemic or hyperendemic. The risk of infection of man is high and for this reason the inhabitants sometimes desert these fertile alluvial lands of the river valleys.

2.6. AREAS WHERE ONCHOCERCIASIS IS FOUND IN AFRICAN COUNTRIES

2.6.1. WEST AFRICA

2.6.1.1. AREAS OF ONCHOCERCIASIS IN THE BASINS OF THE NIGER AND OTHER RIVERS EMPTYING INTO THE ATLANTIC OCEAN

Because the breeding places of the vector and accordingly the areas of onchocerciasis are related to rivers we will examine the nature of the areas where the disease is found in terms of the basins and valleys of the rivers in this part of the continent. (Fig. 3, insertion).

In the basins of the River Niger there are four types of areas of onchocerciasis from the vector S. damnosum; the Republic of Guinea, Mali, the shores of Ivory Coast; Niger, Nigeria, Dahomey; Chad and Cameroon. The valleys bounding the central reaches of the Niger are the northern boundaries of the distribution of S. damnosum in West Africa.

(It extends to 14.5° latitude north in the west, stretching in an arc to 12.18° latitude north in the east).

Along the upper reaches of the River Niger (along the plateau of Mandengo Faranah (Guinea) to Koulikoro (Mali) there are many dams, waterfalls and rapids. The same can be said of its tributaries, the Tinkiso, Bani, Mafu, Niandan, Milo, Sankarani (with the tributaries Dion, Kulai, Guala), Baoule, Bagoe and Banifing. This region has the greatest distribution of onchocerciasis in Guinea and Mali.

GUINEA: (See map, Fig. 3). The first cases of the disease were registered in 1917 [235].

According to the findings of research carried out in 1964-65, mesoendemic and hyperendemic locations of type II were found in the valley of the River Niger between the towns of Faranah and Kouroussa, in the valley of the left-hand tributary of the Niger, the Tinkiso (from Dabola to Ust'ya) and all along the tributaries of the Bani [150].. The Kouroussa region on the River Niger is the main area of onchocerciasis in Guinea [149]. In 1963 in this region a spot-check of 1,588 people from 16 villages was carried out (of whom 1,308 were more than 10 years of age). Onchocerciasis was diagnosed in 63.3% (from 15% to 97.2%) of the people examined in the age group of above 10 years [149]. In seven settlements situated at a distance of one kilometer from the breeding ground of the carrier, 75% of the people examined were found to be infected with onchocerciasis [149]. In the year 1964-65, of 18,634 people living in the Kouroussa region 50% were very carefully examined and microfilarii were found in 45.8% of them. Subcutaneous onchocercal nodules were found in 24.0%. In the settlements where onchocerciasis was hyperendemic, blindness with onchocercal etiology was observed in

4.5% of the cases examined and in the hypoendemic regions it was found in 1.07% of cases [150]. Because of the high infection of the population by onchocerciasis the fertile alluvial land along the banks of the river in this region are deserted.

In the valleys of the eastern tributaries of the Niger (the Mafu, Nianden, Baoule, Milo, Dion, Kulai and Gvala) mesoendemic areas predominate but there are also hyperendemic areas and some of them have been artifically created (by dykes in the rice fields and other forms of water reservoir). In the same territory, in different regions where the rivers (from the River Mafu to the River Gvala) drain an area of about 20,000 square kilometers, there are hypoendemic areas of onchocerciasis. The density of population in the hypoendemic areas is high ---- 10 people to a square kilometer compared to 6.6 people in the hyperendemic areas [150].

Apart from this major onchocercal region, breeding places of the black fly S. damnosum and areas of onchocerciasis of type II are also found in the valleys of other rivers emptying into the Atlantic Ocean; the Kogon; Fatala, Konkure and Kolente and up to the fast-flowing upper reaches of the River Senegal, (Bafing) and its tributaries, the Tene, G. Gambia and Korubal.

MALI: (See map, Fig. 3). The first cases of the disease were registered in 1915 [235].

Mesoendemic and hyperendemic areas of onchocerciasis of types II and III are known in the valleys of the River Niger and its tributaries, the Baoule, Bagoe and Banifing, on the boundaries of the tall grass and typical savanna zone. In the city of Bamako, on the River Niger, two of every three blind people examined were found to be infected with onchocerciasis [9]. The main areas of onchocerciasis (of type II) are in the region of Sikasso near Bougouni (on the River Baoule) and Siklso (on the River Bagoe). The ratio of infectivity of the population is 24 to 46; up to 60% to 75% with a maximum of 94% on the River Baoule and 88% on the River Bagoe. In 1954, 448 inhabitants from five villages on the River Baoule were examined ---- 258 adults and 190 children. Of these 328 (73%) were found to be infected with onchocerciasis of whom 94% were adults and 43% were children [127]. Here, the main maladies of onchocercal etiology are widespread and there are many blind as well [190]. Corneal infections were found in 52% of cases [190]. Hyperendemic areas of type III are known to exist in the southern part of the typical savanna zone in Mali and in the valley of the River Baoule (River Senegal).

In its middle reaches (below the dams of Sotyuba and Kulikoro), the Niger has neither dams nor strong currents and as a result there are many places favorable for breeding of the vector. On this part of the river, in the northern, driest part of the typical savanna near the boundaries of the distribution of the black fly S. damnosum in Africa, only two small hypoendemic areas of onchocerciasis of type IV are known on the small tributaries; in Bandiagara, on the river of the same name, and in Tamu on the River Gorubi. According to the data published in 1967, in Bandiagara 10% to 25% of people were found to be infected with onchocerciasis and in Tamu 17% [232].

A small area of type IV with conditions parallel to those in Mali is found in Eliman, on the River Terekola (basin of the River Senegal). It happens to be the most northern in West Africa (15° latitude north). Of the cases investigated 3% to 20% were found to be infected with onchocerciasis. Severe cases are rare [232].

NIGERIA: (See map, Fig. 3).

The first cases of the disease were registered in 1926 [235]. Onchocerciasis is widespread in this country. The region most affected is the basin of the River Niger. Between Yelwa and Jebba the Niger forms a dam at Bussa. This is a very large breeding ground of the black fly S. damnosum and the region is severely affected by onchocerciasis (type II area). The territory near this region, along the valleys of the many tributaries of the Niger (Malendo, Kontagoro, Manyara, Svashi, Menai, Oli, Nono, Moshi, Teshi, Avun) are also areas of intensive breeding of the black fly and the area is endemic for onchocerciasis. On the River Niger, on the Kandzhi dam, a large hydroelectric power station is at present being built and in this area a campaign was launched in 1962-64 to eradicate the black fly in order to protect the labor from contracting onchocerciasis. Their numbers could only be reduced when the whole territory was sprayed with insecticides, including the valleys of the above-mentioned tributaries of the Niger, covering a total area of more than 33,000 square kilometers.

In 1964 its presence was reduced to 0.1 bite on one man per hour. Below the Dhebby, the river flows according to the rainfall regime and the conditions are unfavorable for the breeding of the vector.

The crystalline plateau of Dzhos, with an altitude of up to 1,200 meters above sea level, creates a watershed between the dense network of the left-hand tributaries of the Niger and the right-hand tributaries of the Benue and other rivers emptying into the Lake Chad. This happens to be the location of a significant incidence of onchocerciasis; it is surrounded on its western, southern and northern slopes (between 8° and 11° latitude north) by areas of onchocerciasis of types II and III. In the center of the plateau there are no favorable places for breeding of the vectors and onchocerciasis pockets are absent.

On the Dzhos plateau, the black fly S. damnosum has been observed over an area of 1,440 square kilometers [67] and onchocerciasis is present over an area of 45,000 square kilometers. Of 339,000 onchocerciasis patients, 20,000 are blind (5.9%), of whom 13,000 are in the working age-group of 10 to 59 years [43, 67, 164].

On an average the percentage of blind people in the endemic areas of northern Nigeria is 10% compared to 0.2% in areas free from onchocerciasis [9].

The people most affected by this disease live in the valleys of the eastern tributaries of the Niger descending from this plateau. Along the River Kaduna from the city of Kaduna to Zungeru, a distance of 224 kms, and its tributaries the Sarkin-Parva, Din'ya, Mariga, and the Rivers Bako and Gurara with their tributaries, Tapa, Ikhu, and Usuman, draining an area of 368,000 square kilometers, the greatest density of S. damnosum in the northern region of Nigeria is found [61-67].

In this endemic region 67,000 people live. The highest incidence of onchocerciasis (type II) is to be found in the triangle formed by the cities of Kaduna, Abuja and Zungeru, (8°33' - 9°30' latitude north 6°50' - 7°35') situated at a height of 420 to 650 meters above sea level. A campaign was mounted against the black fly S. damnosum in the basin of the River Gurary over an area of 1,920 square kilometers with a population of 32,000 people from 1955 through 1960 [37]. This campaign reduced the numbers of black fly appreciably (by 84% to 98%). This brought about a decrease in the percentage of infected inhabitants of the area from 83% in 1956 to 31% in 1960 [37, 67].

In the valley of the **River** Kaduna, the areas around the city of Kaduna and in many other population centers the infection of the population in 1956 was 100% [61]. In this area, too, a campaign against the vector was mounted and the incidence of onchocerciasis among the people was reduced [61]. Breeding places of the vector and areas of onchocerciasis of type II are found on the southern slopes of the River Benue, Madu, Ankve, Shemankar, Vase, Khaval (and the tributary of the Gongola), the Song. On the River Khaval, a campaign against the black fly was waged but the results were not published [300].

A dense network of small hyperendemic pockets of onchocerciasis of type II and an almost continuous distribution of the black fly is also found in the valleys of the southern tributaries of the Benue which drains the Adamasua Massif—the Rivers Temba, Donga, Katsena with their tributaries. The same River Benue flows through graben all the way with no dams and the banks are free from onchocercal pockets.

On the northern slopes of the plateau, areas of onchocerciasis of types III and IV are found in the valleys of the Rivers Galma and Kano. Beyond the Dzhos plateau near the boundary of distribution of _S. damnosum_ in Africa the population of black flies is small in number and uneven. Infection of man with onchocerciasis is sporadic. Isolated, small hypoendemical pockets of type IV are known to exist in the valleys of the River Sokoto and its tributaries, the Zamfara and Ka [61].

A small pocket of onchocerciasis of type I is located on the western tributary of the Niger (downstream from the boundary of the Dzhos plateau) on the River Osse (tributary of the Amambry in the region of Enugu) [60]. A campaign against the vector in this area was mounted in the years 1954-1957 [37].

Infection by onchocerca is also found in the valleys of the eastern tributaries of the lower Niger, the Ohsin, Oro, Kampe, Mimi and others, where small pockets of onchocerciasis of type II are found. The best researched among them is the mesoendemic pocket around the city of Lokoja on the River Mimi. In the city of Lokoja 64% of the population is affected by onchocerciasis [62]. Steps against *S. damnosum* on the River Mimi were taken in 1958 [62, 178].

In Nigeria, onchocerciasis is also widespread in the valleys of rivers draining into the Bay of Guinea that are not part of the Niger River basin. In the forests of the southern part of the country onchocerciasis is so widespread that it is impossible to find a human settlement which has not been affected [44]. In many areas (of type I) of southern Nigeria, cutaneous onchocercal infections are found in almost all the local inhabitants. However, the degree of intensity of infection of the people by microfilaria of *O. vulvulus* is considerably lower than it is in the savanna zones. In these areas severe eye infections are also less widespread.

Among the neighboring countries, onchocerciasis is found along the tributaries of the lower Niger in Dahomey, Chad and Cameroon.

In Dahomey (see map, Fig. 3) the breeding grounds of the black fly around which hypoendemic pockets of onchocerciasis of type IV have been found are in the valleys of the western tributaries of the Niger Rivers — the Mekrou, Alibori and Sota, where the incidence of infection of the population is about 10% [190]. (For other locations in Dahomey see page 178).

CHAD (see map, Fig. 5)

On the eastern tributary of the Benue, the Maio-Kebbi River and its tributaries near the Goto waterfall, around the city of Lere, there is a hyperendemic area of onchocerciasis of type III. Until 1950 onchocerciasis had not been identified in Maiokebbi and the commonly found eye infections were presumed to be due to trachoma, which is also widespread in this region [264].

After 1950, due to a large outbreak of onchocerciasis and the high risk of infection it entailed, the fertile valley of the River Maiokebbi draining an area of 85,000 hectares was almost completely deserted by the inhabitants. From 1955 through 1959, an intensive campaign against the black fly _S. damnosum_ was mounted there. Larvicides and imagocides were used. Though it was not possible to exterminate the black fly completely, its numbers were considerably reduced (from 400 per man hour to fewer than 20). A particularly important achievement was that it was possible to reduce their numbers in the humid season, when transmission of the disease is intense. [9].

Other areas in Chad where onchocerciasis has been found are in the basin of the River Chari. A hyperendemic area of onchocerciasis (type III) is situated around the city of Fort Archembault on the River Chari and its tributaries, the Gribingui, Aouk, Sako, Man, and Moul. In this area the black fly is active only during the humid months of the year. In the dry season the rivers dry up and they vanish. In 1967, 299 people in this area were examined in 11 settlements: 83.3% were found to be infected with onchocerciasis of whom 63.4% had subcutaneous nodules. The main infections of onchocercal etiology were found in 21.5% of the cases examined; blindness was found in 3.5% of cases [156].

Another small pocket of onchocerciasis is known to exist on the River Logone, a tributary of the Chari [261].

2.6.1.2. AREAS OF ONCHOCERCIASIS IN THE BASINS OF OTHER RIVERS

SENEGAL (See map, Fig.3). The first cases of onchocerciasis were registered here in 1945 [266]. The disease is widespread in valleys of the rivers in the eastern province; the Faleme (southern tributary of the River Senegal), the Gambia and its tributary, the Kuluntu. In the valley of the River Faleme, for a distance of 240 kms, from the border of Guinea almost to its confluence with the Senegal, there are numerous breeding places of the black fly S. damnosum and mesoendemic areas of onchocerciasis of type II and type III. In the area near Senedebu, according to data published in 1964, 66% of the local population was affected by onchocerciasis [165]. Eye infections of onchocercal etiology (many blind) and diseases of the lymphatic system (common adenopathy, elephantiasis, hydrocele) are fairly widespread.

In the valley of the upper reaches of the River Gambia mesoendemic and hyperendemic areas of onchocerciasis of type IV are found between Kedougan and Dialakoto. Onchocerciasis was first found in the Kedougo area of Senegal in 1945 [313]. In Dialakoto, in 1963, 50% of the population was found to be infected with onchocerciasis on the basis of 103 cases examined. In many centers the incidence of infection among the population is as high as 87% to 100%. Subcutaneous onchocercal nodules are found in 7.3% to 34% [239]. Females are affected as much as males though children are affected rather less frequently. Onchocercal eye infections are found in 8% to 21% of the cases examined [164, 239]. Infections of the lymphatic system are widespread. Onchocerciasis is also found along the left-hand tributary of the Gambia, the River Kuluntu. In all, 50,000 to 80,000 people are affected by onchocerciasis [164, 239] in eastern Senegal.

Two small pockets of onchocerciasis of type II are known to exist in the middle reaches of the River Kazamans around Sedhiou and Kolda.

PORTUGUESE GUINEA: (See map, Fig.3). In the valley of the River Zheba, onchocerciasis is widespread around the cities of Sonako and Kontuboel (type II areas). Research conducted in 1963 showed that in many settlements 100% of the population was affected by onchocerciasis [265]. Many villages had been deserted by the inhabitants. In the valley of this river, where there is a high density of population, steps were taken to eradicate the vector. They produced a considerable decrease in the numbers of black fly but transmission of the disease could not be checked completely.

Another area of onchocerciasis of type II is known on the River Korubal. However, it is not easy to eradicate the black fly from this location as its breeding places are not easily accessible [265].

SIERRA LEONE: (See map, Fig. 3). The disease was first reported in West Africa in 1901 in Sierra Leone [235]. The black fly S. damnosum is spread throughout the country with the exception of the coastal areas and the hills around the city of Freetown. Onchocerciasis is widespread in the valleys of the Rivers Kaba and Seli and their tributaries, the Tonkolili, Pampana, Rokelle, Sewa and others. According to data obtained from skin biopsies, 30% to 50% of the population is infected with the disease. Hypoendemic areas of type I are the most numerous. The density of the black fly around Port Loko is 250 bites per man hour. From 1955 through 1961 research was conducted around the iron ore mines in the valley of the River Seli to determine to what degree the population was affected by onchocerciasis.

In the city of Lunsar, 380 people (4% of the population) and 1,010 in the surrounding villages were subjected to clinical examination. In the city of Lunsar, 54.5% of the males and 44.5% of the females were found to have infections of onchocercal etiology. The figures for the villages were 40.8% and 52.0% respectively. In the city of Lunsar 80% males in the working age group (from 15 to 54 years) were found to be infected. Cutaneous and eye infections of onchocercal etiology were observed. Blindness was found in 1.1% of males and in 1% of females in the city of Lunsar and in 1.2% of those examined in the villages [204]. In Marampa, in the same area, onchocercal infection of the population is as high as 85%.

In Port Loko the infection of the population is 30%. Eye infections are few, 1.6% [37]. Onchocerciasis is the third-worst disease and the European population is also affected [204, 209].

Steps to eradicate the black fly have not been undertaken on a large scale. Isolated efforts were made on the River Tonkolili from 1957 to 1961 and on the River Seli in 1959 in order to protect the miners in the area /¯37, 300_/. Their numbers were reduced from 23 to 10 per man hour. No further reduction was possible /¯300_/.

LIBERIA: (See map, Fig. 3). The disease was registered here in 1926 /¯46_/. Onchocerciasis is widely distributed (hypoendemic and mesoendemic areas of type I). Onchocercal skin infections are widespread and eye infections are also found among the people living in the northwest and north of the country in the valleys of the upper reaches of the Rivers Mano, Loffa, St. Paul and many others flowing from Sierra Leone.

Considerably less onchocerciasis is found on the banks, with the exception of the valleys of the lower reaches of the Rivers St. Paul and Cavally.

The valley of the St. Paul River (Boporo region) is one of the main areas of onchocerciasis in Liberia. Almost the entire population is infected with the disease. Eye infections of onchocercal etiology are widespread. In Monrovia, of 5,448 people examined for onchocerciasis 6% were found to be blind. /¯214_/.

In the valley of the lower reaches of the River Cavally 125 adults living on the rubber plantations (within 27 kms of the river) were examined in the period 1963-64. Of these 6% had microfilaria in the skin; 53% had subcutaneous nodules (hyperendemic area). Infections of the lymphatic system (elephantiasis and hydrocele) and eye infections of onchocercal etiology were also found /¯203/. In the region downstream, onchocercal nodules were found in 29.4% of the males examined and in 14.4% of the females. /¯110_/.

Hydrocele was found in 12% of all the cases treated surgically for the disease in southeast Liberia [110].

Infection of the population is also found along the upper reaches of the River Cavally as it runs along the Ivory Coast border as well as along the middle reaches of this river.

IVORY COAST: (See map, Fig.3). Onchocerciasis is widely distributed in the central and northern parts of the country.

In the north, an important agricultural region, onchocerciasis presents a serious danger. Mesoendemic areas of type II are many in the valleys of the White Bandama River and its tributary, the Bu (in subprefectures Sinematiali, Firkessedougou, Korkhogo, Napieoledugu, Siraso, Dikodugu, Niakaraconandugu), and in the valleys of the upper reaches of the Rivers Baoule and Bagoe and its tributary Makhandiani.(in subprefectures Odienne, Boundiali, Guiglo), Gulia, and Gbon [246]. In this endemic zone, which covers an area of 4,240 square kilometers, nearly 40,000 people live [300].

In the rainy season the number of black flies is as high as 400 per man hour; in the dry season it is 7-10 [300]. Their overwhelming number make life in these areas unbearable and seriously hinder agriculture. In the period 1962-64 entomological research was conducted. Larvicides were used for the first time in 1965 in an attempt to reduce the number of flies and bring transmission of onchocerciasis to a minimum. The results are not yet known [300].

There are many areas of onchocerciasis in the northern part of the country as well, in the upper reaches of the Sassandra and Comoe Rivers. The endemic zone in the valley of the Comoe extends to Upper Volta (around Lerab and Banfora).

In the central part of the country, which is mainly forest there are many endemic areas of onchocerciasis but on a less dangerous scale. Eye infections of onchocercal etiology are rarely found. Type I areas occur in the valleys of the middle reaches of the White and Red Bandama Rivers and their tributaries in the subprefectures, Katiola, Beoumi, Sakasu, Tiebissou and Bvafle and the lower reaches of the Bandama and its tributary, the Nzi, in the subprefectures Oume, Tiassale, and Dabu [246]. In the valley of the Sassandra River breeding places of the fly and areas of onchocerciasis are found in the subdivisions of Bako, Urofla, Biankuma, Fakobli and Kvibli, and in the valley of the Comoe in the subdivision of Alepe.

In some villages of the endemic zone in central Ivory Coast as much as 70% of the adult population is infected with onchocerciasis. There are also some hyperendemic areas of type I, as found from skin biopsies taken from the inhabitants of these areas, but they do not exceed 10% to 15% of the total territory [246]. In 1965 it was proposed to undertake an eradication program against the flies but the results are not yet available [300]. People living along the small rivers emptying into the Gulf of Guinea, such as the Ko, La and Me in the Adzope subdivision and the Bia in districts Aboiso, Kan and others are also infected with onchocerciasis [246].

2.6.1.3. AREAS OF ONCHOCERCIASIS IN THE BASIN OF THE VOLTA

The people living in the valleys of the Black, Red and White Volta Rivers and their tributaries are widely infected with onchocerciasis.

The three Volta Rivers flow through places where many rapids, dams and waterfalls are formed. In the valleys of these rivers, breeding places of black fly S. damnosum are to be found along the banks of the reservoir of the hydroelectric station in Akosombo and in an almost continuous belt from $12^{o}40'$ latitude north to the banks of these rivers, of which only the Black Volta is perennial. The White Volta and Red Volta and their tributaries dry up in the dry season.

One of the most widespread regions of onchocerciasis in West Africa is situated along the three Voltas extending into Upper Volta, Ghana, Ivory Coast, Congo and Dahomey. All four types of areas are found, the vector being S. damnosum.

UPPER VOLTA : (See map, Fig. 3). The disease has been known to exist here since 1938-1939 [235]. The number of onchocerciasis patients according to data obtained from research carried out during the years 1962 to 1967 was approximately 280,000 of which 150,000 live along the White Volta and its tributary, the Sisili, the Red Volta and middle reaches of the Black Volta up to Nuqo, Kompanga, and Pendzhari; 120,000 live in the southwestern part of the country, in the basin of the upper reaches of the River Comoe (in the Lereba and Banfora region) and the upper reaches of the Black Volta and its tributaries, the Buguriba, Garango, etc. (in the Plandi, Guenaka and Kiani region); 10,000 live in the northern part of the country (to the upper reaches of the Black Volta and the Niger tributaries of Sirba and Diamonga) [251].

The disease increases in intensity with the increase in humidity. In the northern endemic region, in the valley of the White Volta River, near the boundary of distribution of S. damnosum ($12^\circ 40'$ latitude north) there is a hypoendemic area of type IV where only 3% to 4% of the inhabitants are infected. Severe onchocerciasis infections are rare [232] toward the south (in the districts of Tenkodogo, Ouagadougou and Kombisiri) though the degree of infection is rather high: 10% of the patients have subcutaneous nodules and eye infections are also found among them, 2.3% of which have caused blindness [234]. Still further south (in the districts of Po, Tiebele and Gaongo) near the Ghana border, 60% to 90% of the population is infected, the average infection being 38%. Eye infections (sclerotic keratitis, irridocyclitis, chorioretinitis) are found in 30% of onchocerciasis patients in this area. Of these, 13% to 35% become blind [136]. Elephantiasis is widespread. The most severely affected districts are the Po, Leo, Diebougou, Lumana and others [164]. In the valley of the Black Volta River 53.5% of the male, 43.6% of the female population and 16.6% children were found to be infected in 1950 [135]. The highest incidence of infection was 86.4% in cantons of Kulni, Bunde and Kurignon. An average of 20% of the population had onchocerciasis, of whom 10% had subcutaneous onchocercal nodules. The valleys of the tributaries of the Black Volta, Buguriba and Garango Rivers are also hyperendemic areas. A pilot project to eradicate the black flies was undertaken along the upper reaches of the Black Volta in the period 1962-63. The river and its five tributaries were sprayed with larvicides. The number of flies was reduced considerably but 18 months later the territory was again invaded by the black fly and their numbers again increased [300].

GHANA: The first case of the disease was registered in 1908 [279]. Hyperendemic areas of onchocerciasis of types II and III are particularly prevalent between 11° and 10° latitude north in the valleys of all three

Volta Rivers and the tributaries of the White Volta (the Sisili, Kan'yanbiya, Kulpon, Kamba, Bekpong). In this part of the country almost 1,000,000 onchocerciasis patients have been counted and nearly 90,000 have been blinded by the disease [19]. A particularly large number of blind were found along the Rivers Sisili and Kan'yanbiya. Infection of adults in each settlement is as high as 80% to 100% and the number of blind 30% to 35% [279]. Elephantiasis of the genitals is not as frequent as it is in Upper Volta. Onchocerciasis is the main reason why the fertile land of the region is not cultivated and is deserted. [139].

Large-scale campaigns against the black fly were mounted in northern Ghana in the period 1954-60. Attempts were made to spray larvicides in particular places along the Red Volta, Sisili, Kan'yanbii and Kamba but they failed to reduce the numbers of the black flies. Only in 1960, as a result of spraying of breeding places along the Black Volta, Kambe and Bekponge, was it possible to bring down their numbers to 20 per man hour [300].

In the lower reaches of the River Volta onchocerciasis among the local population is 48% to 68% between the towns of Ak-vapim, Akim and Abuaka [261]. In the period 1962-64 a campaign against the black fly was mounted along the lower reaches of the Volta with a view to protecting the builders of the hydroelectric station at Akosombo. After the reservoir was filled in 1964 the environmental requirements of onchocerciasis changed sharply in this region and as a result of the raised water level the breeding places of the fly were destroyed. However, their larvae could have moved to water pools nearby.

Some breeding places remained under water but they were few in number.

The index of their presence is 0.02 to 0.7 per man in one hour [300]. Low incidence of onchocerciasis in Ghana is also to be found in the valleys of the small rivers which flow from the Ashanti plateau into the Gulf of Guinea (the Pra with its tributaries, the O-fin, Birim, Ankobra and others).

Type I areas of onchocerciasis in the basins of these rivers are found in the towns of Beposo, Akituase, Daboasa, Sekondi, Takoradi, Prestea, Tarkwa, Kaara and others [261]. In the Akavata area on the River Birim, a tributary of the Pra, the incidence is 68% to 82%. Eye infections were found in 7% of the population [138]. Genital elephantiasis and hydrocele are also found [138].

TOGO AND DAHOMEY: (see map, Fig.3). The first cases of onchocerciasis were registered in these countries from 1936 through 1938 [235]. It is distributed in the northern regions of these states: in the valleys of the tributaries of the Volta River, the Oti and its tributaries, the Keran, Kara and Pendzhari (type III areas). The incidence of infection is 10% to 20%.

In the southern regions of Togo and Dahomey, small pockets of onchocerciasis of type II are found in the valleys of the Rivers Mono and Oueme. In the lower reaches of the River Mono in Dahomey, 221 people were examined of whom 38.6% were found to be infected with onchocerciasis; 140 had eye infections of onchocercal etiology and three were blind [237]. In the valleys of the River Oueme (Dahomey) and its tributaries, the Zu and Okpara, the black fly S. damnosum is abundant in the rainy season. In the dry season it vanishes and transmission of the disease does not take place [237].

A number of experimental programs to eradicate the black fly from the basin of the Oti have been adopted as preliminaries to a long-term campaign against them.

2.6.2. EQUATORIAL AFRICA

2.6.2.1. AREAS OF ONCHOCERCIASIS IN THE BASINS OF THE CONGO AND OTHER RIVERS EMPTYING INTO THE ATLANTIC OCEAN

Areas situated in the basin of the River Congo in the Democratic Republic of Congo (Brazzaville), Angola and the Central African Republic, in equatorial and tropical latitudes, are heavily infected with onchocerciasis. The registered areas are right on the River Congo and on its many tributaries (Fig. 4, insertion).

CONGO (KINSHASA): (See map, Fig. 4): Onchocerciasis has been known here since 1904 [235]. In the valley of the upper reaches of the River Congo (Lualaba), at an altitude of 1,200 to 1,500 meters above sea level, onchocerciasis of local origin is not registered despite the presence of S. damnosum. However, instances of the infection being imported from elsewhere, mainly from neighboring endemic regions, have been observed.

In the middle reaches of the River Congo a hypoendemic area of onchocerciasis of type I with both vectors, S. damnosum and S. neavei, is found 30 kms downstream from the city of Kisangani in the tropical rain forest zone of between 23° and 25° longitude at an altitude of 410 to 480 meters above sea level.

From the data obtained in research conducted in the period 1959-60 in this area, 17.3% of the inhabitants (415,035 examined) were found to be infected with onchocerciasis. The surrounding areas of Bokuma and Benbeloty are hyperendemic and subcutaneous onchocercal nodules were found in 34% of the 12,999 people examined, both adults and children. The adult male population is particularly badly infected with onchocerciasis. Subcutaneous, onchocercal nodules were found in 82% of adult males [38]. Onchocercal skin infections are widespread. Eye infections of onchocercal etiology were found in 85% of 1,026 adults examined (0.08%). In 30% of the adults infections of the lymphatic system (edema, genital elephantiasis) were found. Elephantiasis of the feet was not found. Campaigns were waged against the vectors of the disease but only a temporary respite was achieved. Four months after the spraying the numbers were the same [300].

In the lower reaches the River Congo flows 400 kms through the south Gabonese crystalline plateau, which forms the Livingstone Falls. This is a hyperendemic area of onchocerciasis of type II, affecting both banks of the river in the Republic of Congo (Kinshasa) and Congo (Brazzaville). Larval colonies of the black fly *S. damnosum* are found in the stony arms of the river over an area of three to four hectares and on the islands in the river.

This region has been well described in Wanson's work [282]. The people most affected by onchocerciasis are those living in the villages situated on the left bank of the river (Congo, Kinshasa) close to the dams at Kinsuka, Mbudi, Lutesse, Gombe, Sabuka and others, who are constantly exposed to the bites of the black fly *S. damnosum*. Microfilaria among the adult population of these villages is 100%; subcutaneous nodules are found in 58% to 80% of the inhabitants; 60% of the children between nine and 15 years of age are carriers of the parasite. Severe eye infections are wisespread and there are many blind. Microfilaria in the conjunctiva was found not only in those with eye infections but in 60%

of those with subcutaneous nodules as well, though they did not appear to be suffering from the eye infection.

In the capital of Congo, Kinshasa (formerly Leopoldville), onchocerciasis is a most serious problem. From 1934 through 1948 the number of S. damnosum in the city was enormous, sometimes more than 600 per man hour. Most severely affected by onchocerciasis were those living in the western part of the city close to the river banks, where 100% of the Africans and 45% of the Europeans were infected. Cutaneous microfilaria was found in 18% of 462 cases of children under 10 years of age who were examined and subcutaneous nodules were found in 9% cases. Among those infected with onchocerciasis, onchocercal eye infections were the most widespread (punctate keratitis) and the incidence of blindness was 5% [282]. In the eastern part of the city which is further away from the river, 5% to 11% of the people were infected with onchocerciasis.

On the right bank of the Congo (Congo, Brazzaville) there is a hyperendemic area about 100 kms downstream from Brazzaville in the town of Boko. In Boko, 57% of the 1,075 people examined were found to have subcutaneous onchocercal nodules. Many were found to have severe eye infections and there were many who had become blind due to onchocerciasis.

Areas around the small western tributaries of the Congo (the Dzhve, Fulakari, Luva, Zumuna, Brazzaville) are endemic zones. Along the River Dzhve a mesoendemic area of type II extends for a distance of 50 kms from Ustiya to the town of Mayama. An average of 20% of the inhabitants (899 examined) had subcutaneous onchocercal nodules, cutaneous and eye infections. There were many blind among the older people.

A program for the control of black fly, the vector of onchocerciasis, has been in operation along the banks of the lower reaches of the Congo since 1942. In the period 1942-44, at the time when the water level of the Congo was lowest, the weed *Pennisetum nodoflorum*, which the black fly *S. damnosum* attaches itself to in the larval stage, were destroyed with insecticides. About 65,000 Pennisetum were pulled out by the roots and burned. The larvae attached to stones and fishing nets were scraped off and destroyed. The branches of the trees used by *S. damnosum* were cut off and the mass of floating grasses, vossia and echinochloa was also destroyed. This produced a considerable reduction in the numbers of the insect but did not lead to complete eradication.

In 1948, in this part of Congo (Kinshasa), a project was undertaken to destroy the imago of *S. damnosum* by aerial spraying of the breeding places on the east bank and islands of the river for 26 days from October 10 through November 4. Within the first two days of spraying a positive effect was achieved. The western parts of the city of Kinshasa became almost free from the black fly and on the fourth day the people of the area were completely free of bites as well as the inhabitants of villages situated within a radius of 35 kms from the river bank. On the 21st day after spraying began it was found that all imago and larvae of *S. damnosum* had been destroyed.

In March and April, 1949, it was found necessary to spray the right bank of the River Congo and its tributaries (the Dzhve, Fulakari, Zumune and Luva) situated within range of the black fly. Since then *S. damnosum* has been almost completely eradicated from the city of Kinshasa and surrounding areas. Transmission of onchocerciasis stopped abruptly. In 1947, 40,000 to 50,000 mature black flies were caught in one place. In 1949, not more than 20 flies a year were caught and they must have come from the river. Not one breeding place reappeared and not a single new case of onchocercal infection was found.

Of 86 children born after January 1, 1949, no carrier of microfilaria was found among them. There were no new cases of infection among the Europeans either. This success was probably due to the fact that the breeding place of S. damnosum geographically coincides with the main breeding places of malaria-carrying mosquitoes, anopheles gambiae, and the anti-malaria spraying which has been carried out regularly in Congo (Kinshasa) since 1952 interfered with the reestablishment of S. damnosum. However, S. damnosum are still occasionally caught on the islands near the banks of the river and on its western tributaries.

Spraying of the breeding places of S. damnosum was carried out yearly from 1949 through 1957. The annual reports of the Health Department in the years 1954, 1956 and 1957 indicate that there are no breeding places of S. damnosum left on this river [86]. After 1957, annual spraying continued but on a smaller scale.

Up to 1960 S. damnosum did not reappear in the city of Kinshasa [37]. The number of new cases of onchocerciasis was almost nil. Not such good results were achieved from regular spraying and mixing of larvicides in the reservoir built on the river Dzhve (Congo, Brazzaville) in 1959. Six months after spraying S. damnosum again appeared and in 1960 they had almost attained their initial numbers. Considering the high incidence of infection among the African population living along the lower reaches of the Congo, this reestablishment of the breeding places of the black fly on the River Dzhve presents a serious threat to the whole endemic area and needs to be kept constantly under control [86].

Further down the river, near the Livingstone Falls, no systematic research on onchocerciasis on either bank of the river has been carried out. The region is known only through some research conducted on the eastern bank (in Congo, Kinshasa) in 1945, near the towns of Kimpese and Songololo, which is 100 kms upriver from Port Matadi. In these two towns 47% to 70% of the population is infected.

The black fly S. damnosum is also known to frequent the small eastern tributaries of the lower reaches of the River Congo; the Vsele, White and Blue River, Mfuti, Lukunga (Congo, Kinshasa).

AREAS OF ONCHOCERCIASIS IN THE VALLEYS OF THE RIGHT-HAND TRIBUTARIES OF THE RIVER CONGO

In the mesoendemic area of type II along the River Luama near the city of Maniem, of 186 examined in the over 10 years age group 66.3% were infected with onchocerciasis. Only a few cases of eye infections and genital elephantiasis were found [206].

There is a mesoendemic area of type I in the valleys of the River Aruwimi and its tributaries, the Nepoko and Ituri [86]. The main vector is S. damnosum. On the River Nepoko, larvae and pupae of the second vector, S. neavei, were found on crabs Potamon dubowskii.

Onchocerciasis was reported on the River Aruwimi in 1920 [86]. On the river Nepoko, near Pava, 30% to 40% of the adult population was found to be infected with onchocerciasis (1940); genital elephantiasis was found in 0.2% and elephantiasis of the feet in 0.3% to 6% [86]. In the valley of the River Ituri, near Kilo, 40% of the pygmies were found to be carriers of microfilaria O. volvulus [233]. Of those above 15 years, 64% of the 110 examined were found to be infected. In the valleys of the Rivers Ituri and Epulu, subcutaneous onchocercal nodules were generally found in the pygmies of Mombasa when they were examined in 1962 [140]. Onchocerciasis was diagnosed in two Europeans in Putnam, Connecticut, who had lived for some years in the valley of this river and had not visited any other endemic onchocerciasis area [84].

Areas of onchocerciasis of type I are known in the valleys of the Itimbiri, Likati and Rubi, where there is a high incidence in the towns of Buta, Ibemo, and Ekvangatana [86]. On the River Rubi, near Buta, 20% to 30% of the population were found to be infected in 1916 [86]. In Ekvangatana and Buta more than 90% of the adult males of the 350 examined in 1941 were found to be carriers of cutaneous microfilarie and more than 80% had subcutaneous, onchocercal nodules [31]. In these parts, genital elephantiasis is widespread in the valley of the Itimbiri where it joins the Rivers Likati and Rubi. The incidence of infection among the coffee plantation workers in 1934 was 90%.

Areas of onchocerciasis occur in the valleys of the River Ubangi and its tributaries, the Uele and Mbomu. Areas of onchocerciasis of types I and II in the valley of the River Uele are found between the towns of Aba and Bondo and along its tributaries, the Kibala, Bomokandi, Bima. Onchocerciasis is particularly rampant in the lower and middle reaches of the River Uele (in the towns of Bondo, Angu, Bambili, Ekibondo, Niangara and Dungu) but is slightly less intense in its upper reaches (from Gungu to Aba). In the recent past, larvae of S. damnosum have been found on crabs P. farandejensis in the River Kibala.

In the lower and central reaches of the River Uele onchocercal infections among the local inhabitants are very common. In 1916, onchocercal nodules were found in this area in 50% to 60% of the adults examined and in 15% to 20% of the children. In 1934 along the lower reaches of the River Uele, 88% to 95% of the adults and 61% of the children of six to 12 years were found to be infected [136]. According to data published in 1941, 88.2% were carriers of microfilarie and 81.9% had subcutaneous onchocercal nodules [31]. In 1950 the number of carriers of microfilarie in this region was 63.3% and the number of those with subcutaneous nodules was 61.2% [282].

In the valley of the upper reaches of the River Uele, from Dungu to Aba, the incidence of infection among the adult population decreases to 12-20% except in the towns of Amai and Aba, where the number of those with nodules is as high as 68% [282].

Eye infections of onchocercal etiology in the areas of onchocerciasis in the basin of the River Uele are rare. In 1934, eye infections were found in 2.1% of 3,448 inhabitants examined and the number of those blind from onchocerciasis was 0.4% to 0.5% [136]. Of eye infections, punctate keratitis was the most widespread. Elephantiasis of the genitals is more commonly found in the valley of the River Uele than in any other region of Congo (Kinshasa). Every case of elephantiasis is caused by O. volvulus [136]. Most of the cases of genital elephantiasis were found in males over 20 (90 cases); five cases were found in the age group 10 to 15 years and one case in the age group five to 10 years. Elephantiasis of the feet is rare. Some cases of adenopathy and chyluria are known [86].

A hyperendemic area of type II is found in the valley of the River Mbomu between the towns of Zemlo and Yakoma in the Central African Republic. Onchocerciasis among the local inhabitants of this region was reported for the first time in 1913 [277].

In 1950, around the town of Rafal, 24% of the 1,198 inhabitants examined were found to have subcutaneous onchocercal nodules: cutaneous and eye infections were also found as well as edema and genital elephantiasis. Elephantiasis of the feet is rarely found here [282]. Around Bakuma, 57% of the population examined were found to have onchocercal nodules. Bauda and Kokada [86] are endemic townships.

In the valley of the central reaches of the River Ubangi, between Yakoma and Banzyville in Congo (Kinshasa), cases of genital elephantiasis were found among the inhabitants in 1940 [86]. The vectors of onchocerca have not been researched in this region. On the lower reaches of the River Ubangi onchocerciasis has not been registered [86, 244].

AREAS OF ONCHOCERCIASIS IN THE VALLEYS OF THE LEFT-HAND TRIBUTARIES OF THE RIVER CONGO

Isolated pockets of type I are known along the lower reaches of the River Lomani (between Obendzhe, Bendzhe and Opala) and along its tributaries, the Lobae and Elipa. The main vector is S. damnosum. Larvae of S. neavei are found on the crab Potamon lirrangensis [86].

In 1930, many cases of onchocercal infection among the local inhabitants were known. Eye infections were also registered [256]. In 1932, it was thought that onchocerciasis might have been transmitted to the upper reaches of the River Lomani. There has been no proof of this [258].

A small, isolated, hyperendemic pocket of onchocerciasis of type I is known on the Congo tributary, the River Lopori, around Yahuma. According to data obtained in 1949, microfilarie were found in 49 of the 54 males examined (90.7%) [86].

In the basin of the Congo, where there are tropical rain forests, the incidence of onchocerciasis is difficult to assess because of the small scattered population, few medical personnel and lack of communications facilities.

In the villages on the Rivers Ruki and Isodzhi, around Mbandaka, the average percentage of infection among the population, according to data published in 1965, was 3.5% [86].

Around Befale, on the River Maringa, of 148 adults and children examined 92 (65%) were found to have subcutaneous onchocercal nodules and 59 (41.2%) had eye infections; of these eight (0.13%) were blind. Patients of onchocercal eye infections were found in Basankusu, Boende, Monkoto, Bumba and Ingende [86].

The vectors of onchocerciasis in the basin of the Congo in the tropical rain forest zone (Congo, Kinshasa) has not been studied [86].

Areas of onchocerciasis are found in the basin of the River Kasai and its tributaries. A hyperendemic area of type V along its tributaries, the Sankuru, Lubilas, Bushimae and Lubi, on the plateau of Lunda is known at an altitude of 800 meters above sea level. The main vector in this area is the black fly *S. neavei*. *S. damnosum* is a secondary vector.

The natural infection of *S. neavei* is 33.3% [86]. The role of *S. neavei* as a vector of onchocerciasis and as a transmitter of *O. volvulus* was first determined in 1932 [131].

It was found that 73% to 95% of the local inhabitants had a great many subcutaneous, onchocercal nodules [131]. According to data published in 1958, 58% to 77.3% of the adults of this area had subcutaneous onchocercal nodules [73]. There was also a high incidence of eye infections. In 1932, 43.5% of the infected inhabitants in the valley of the River Sankuru had severe eye infections and 20% of them were blind. Patients with severe eye infections generally had a great many subcutaneous nodules on the upper parts of the body (head and shoulders). In 1958 37% to 38% of the adults were reported to have eye infections [73]. High incidence of severe cutaneous infection was also reported. Genital elephantiasis was rarely found.

Mesoendemic pockets of type II are found in the valleys of the Rivers Kasai, Lulua, Luembe, Lutshima, Chicapa and Luvua. The black flies *S. damnosum* and *S. neavei* are the vectors. Larvae of *S. neavei* were found on crabs *P. luebonsis* and *P. lirrangensis*. In 1958, 14.64% of the 81,130 inhabitants of the valleys of these rivers who were examined had subcutaneous, onchocercal nodules [73]. Eye and skin infections were widespread. Elephantiasis was rarely found. This area extends into Angola. An insignificant incidence of onchocerciasis is found among the people living between the Rivers Loange and Lushiko.

Mesoendemic areas of onchocerciasis are found in the valleys of the Rivers Kasai, Kwilu, Kwango, Inzia and Wamba. At the confluence of the Rivers Kwango with the River Kasai near the city of Bandunda the number of carriers of microfilarie among the adult population in 1947 was 10% (755 examined) [80]. Approximately the same percentage of the population had subcutaneous, onchocercal nodules.

In the valley of the River Kwilu, from its confluence with the River Kwango to its confluence with the River Inzia, 50% of the inhabitants were found to be infected with microfilarie *O. volvulus* in 1950 (135 examined). Below Bagata, in the valley of this river, only 11.3% (202 examined) of the inhabitants were found to be infected. Where the River Inzia joins the River Kwilu, 45% of 81 people examined were found to be infected in 1950 [97]. Eye infections were not observed.

The highest incidence of infection in the valley of the River Inzia is found 200 kms upstream from this point (between 5° and 6° latitude south and 17°40' longitude) at an altitude of 800 meters above sea level where there is an isolated, hyperendemic pocket of onchocerciasis of type V. The pocket extends along the river and its three small tributaries. The vector is *S. neavei*. The larvae of *S. neavei* develop on crabs *P. lueboensis* and *P. lubowskii* [97]. In the villages of Mvana Bazila, Trako-Tsakosi, Tombuta, Nogombo, 100% of the adult population was found to be infected (464 examined) in 1950 [97]. The number of infected children below 10 years of age was 8% of 83 examined [97]. In spite of this high incidence of infection, eye infections in this area are rare, affecting less than 1%. During a survey made of 500 male and 850 female onchocerciasis patients not a single case of elephantiasis was found [97].

At the junction of the Rivers Kwango and Wamba 25 of 29 people surveyed (86.7%) [80] were found to be carriers of microfilarie. Nearly 10% of the local inhabitants had subcutaneous nodules. *S. damnosum* is the vector. Nothing of significance is known about the presence of S. neavei in this area [̅86̲]. There is a mesoendemic area of onchocerciasis of type II where the River Kwango joins the Kwilu on the Popokabaka Plateau. Of 135 adults examined, 50% were found to be infected [̅80̲]. Eye infections were not found.

CONGO (BRAZZAVILLE): (See map, Fig. 4). The first cases of onchocerciasis were registered in 1921 and 1922 [̅235̲] among the inhabitants of the valleys of the River Nidri and its tributaries, the Luvisi and Minduli, (for the incidence of infections among the inhabitants of the valleys of the small right-hand tributaries of the lower reaches of the River Congo, see above), and on the River Niari, in Ludima, Madingu and Mfuati, many carriers of microfilarie O. volvulus [̅220̲] were found. Areas of onchocerciasis of type II predominate, with a low incidence of infection among the population. In Madingu, the percentage of those with subcutaneous onchocercal nodules was 3.5% of the 1,916 examined in 1953 [̅220̲]. On the River Minduli 23% adult males of 1,500 surveyed had subcutaneous nodules and 37% were infected with microfilarie O. vulvulus [̅220̲]. Skin and eye infections were found among them.

CENTRAL AFRICAN REPUBLIC: Apart from the endemic areas in the valleys of the Rivers Ubangi and Mbomu in the Congo basin (see above), areas of onchocerciasis of type II are found on the tributaries of the River Chari, Gribingui (around the city of Fort Crampel) and the Ouham near Bozoum and Bouar [̅261̲]. Onchocerciasis has been known here since 1913 [̅235̲].

2.6.2.2. LOCATIONS OF ONCHOCERCIASIS IN THE BASINS OF OTHER RIVERS

CAMEROON: (See map, Fig. 3). The first cases of the disease were registered here in 1919 [̅235̲]. Mesoendemic areas of onchocerciasis of type I in tropical rain forest zones with a 50% incidence of infection are found in the basin of the River Mungo (and its tributaries, the Kumba, Etam, Batuma, Ikilivindi, etc.) and in Kumba, on the slopes of the Cameroon Mountains and in the basins of Nkam, Sanaga and their tributaries, the Mbam, Nun, N'ong and others.

Onchocerciasis is very widespread in the southern forest region of Cameroon among the people who live in the valleys of the rivers descending the slopes of the Massif de l'Adamaqua (the River Ntem and others). In the forest zone of Cameroon, as in Nigeria, it is almost impossible to find anyone from any village who is not infected with onchocerciasis. In south Cameroon, areas of onchocerciasis of type I, with a low incidence of infection among the inhabitants (about 5%), predominate [75]. Skin infections of onchocercal etiology are widespread.

In the northern part of the country onchocerciasis is known in the valley of the River Maio-Kebbi flowing from the neighboring country of Chad.

EQUATORIAL GUINEA: (See map, Fig. 4). The disease has been known in the country since 1911 [48]. It is widespread in the valleys of the Rivers Campo, Benito and Kogo and in the north and east of the island of Fernando Poo (type I area). In 1962, onchocerciasis was found in 119 (3.9%) of 2,979 people examined, 74 of whom were inhabitants of Fernando Poo and 45 from the province of Rio-Muni [48]. Most of the patients were over 30 years of age. Subcutaneous, onchocercal nodules and various skin and eye infections of onchocercal etiology were reported.

GABON: (See map, Fig. 4). Subcutaneous onchocercal nodules were first reported in 1914 among the people living along the Rivers Okano and Dzhuakh in the north of Gabon and between 1932 and 1933 in the area between the Rivers Ogone and Niyamga [244]. The valley of the River Ougoue is heavily infected with onchocerciasis. Areas of onchocerciasis are known along its upper reaches near the city of Franceville (type II) and in the central reaches of the river near Latourville (type I) [220, 261].

Small pockets of onchocerciasis are also known on the tributaries of the River Ogoue and Sebe, near Okongo, along the upper reaches (type II), the River Okano, between Mitzic and Allem in the region of Vole-Ntem (type I) and on the River Ngume between N'Dende and Mouila in the region N'gounie [220, 261]. In the basin of the River N'yanga an area of onchocerciasis of type II is found near Chibanga (N'yanga region) [261].

Cutaneous, onchocercal infections predominate. The incidence of infection among the population is low.

2.6.3. SOUTH AFRICA

2.6.3.1. AREAS OF ONCHOCERCIASIS IN RIVER BASINS

ANGOLA: (See map, Fig.4). The disease was first registered in Angola in 1945. Areas of onchocerciasis (type III) are widespread in the northern part of the country along the tributaries of the River Congo in the provinces of Zaire, Vizhe and Lunda. However, the incidence of infection among the population is not very high; it is 4.55% (110 examined), 29.45% (601 examined) and 6.17% (73,273 examined) respectively [50]. In the provinces of Zaire and Vizhe, *S. damnosum* is the vector and in Lunda it is *S. damnosum* and *S. neavei*. Larvae of *S. neavei* develop on crabs *P. depressus*

[86]. Apart from the endemic areas in the north, onchocerciasis is also found in the valleys of many fast-flowing rivers emptying into the Atlantic Ocean (type III areas). In the provinces of Luanda, north Cuanza, South Cuanza and Bie, the incidence of infection among the population is 31.55% (634 examined), 50.39% (1,417 examined), 38.61% (101 examined) and 26.79% (2,221 examined) respectively [51]. The best known areas in these regions are found in the basins of the Rivers Dande and Cuanza.

Areas of onchocerciasis are found along the tributaries of the Dande, Ucua Pango and on the Alukem (with its tributary, the Muvindo). In the park savanna zone, 560 inhabitants over five years of age were examined of whom 300 (53.6%) appeared to be carriers of microfilarie, O. volvulus. Of these, 161 (56.9%) were men and 139 (50.2%) were women. The incidence of infection among the inhabitants of the Ucua River varies from 34.6% to 76.6%. Examination of 100 inhabitants of the valleys of this river conducted in 1959 showed that 60% of them had cutaneous microfilarie and eye infections and 7% were blind [141]. Steps against the vector of this disease have been taken in the valley.

In the basin of the River Cuanza, two areas of onchocerciasis of type II are known in the valleys of its tributaries; in the valley of the River Lukala and its tributaries and in the valleys of the Konzo, Kunzhe, Okulongo, Kukuema and Kuito.

In the onchocerciasis area in the valley of the River Lukala, the percentage of carriers of microfilarie, according to data published in 1955, varies from 14.3% to 97.1% [172]. Of 1,000 cases examined in this area, 574 (57.4%) had skin microfilarie; 262 of 438 males (59.8%)

and 312 of [illegible]2 females (55.5%) [172]. The incidence of onchocerciasis among the inhabitants according to age group was as follows: 16 to 30 years, 5.7%; 31 to 50 years, 22.1%; above 50 years, 35.2% [172].

The area of onchocerciasis along the Rivers Konzho, Kunzhe, Okulongo, Kukuema and Kuito in Novo cintra, Catabola, Zheneral, and Mashadu (Kamakupa) is the southernmost in Africa. In 1955, 1,047 inhabitants of this area were examined, of whom 43% were found to be carriers of microfilarie and 32% had subcutaneous, onchocercal nodules. Eye infections of onchocercal etiology were found in 11.4% of those examined and blindness was found in 6% [49]. In 1961, in the Catabola region, 68% of the 200 inhabitants examined were found to have onchocercal, cutaneous and eye infections [141].

The incidence of infection among the inhabitants of Kabinda and Buko-Zau was 40.17% of the 239 persons examined [86].

2.6.4 EAST AND NORTHEAST AFRICA

2.6.4.1. AREAS OF ONCHOCERCIASIS IN THE BASIN OF THE RIVER NILE

UGANDA: (See map, Fig. 4). The disease was first registered in Uganda in 1938. It is transmitted by both the vectors, _S_. _damnosum_ and _S_. _neavei_.

The largest breeding places of _S_. _damnosum_ are found at two points on the River Victoria Nile, between Lake Victoria and Lake Kyoga and between the dams of Amin near the Karum Falls and Lake Albert; they are found on the small tributaries of the river at an altitude of 1,136 meters above sea level.

Two large areas of onchocerciasis (type II) are found around the breeding places of the black fly in this region. The incidence of infection among the people of these areas as of 1950 was 80% to 100%. Steps to control the black fly have been taken since 1952 in one area. Measures to control the vector were undertaken to protect the laborers building the dam and hydroelectric station at Owen Falls and the black fly was eradicated. But in 1953 it reappeared in the area. Further spraying carried out in 1956, 1961 and 1964 resulted in only temporary reduction of numbers; complete eradication was not possible.

After the last spraying of the area, in 1964, the number of black flies remained at a low level. As a result of these attempts 225,000 people in an area of 4,114 square kilometers were protected from onchocerciasis [300].

Attempts in 1959 to eradicate the vector from the second area, around the Murchison Falls, were not completely successful either because even while spraying of the breeding places was in progress the fly appeared in the smaller tributaries of the river. By 1960 the black flies were back to their original strength [9].

Areas of onchocerciasis of type V are known in the northern, western and eastern provinces of the country. In the northern province of Uganda, the black fly _S_. _neavei_ is found in large numbers over an area of more than 5,000 square kilometers. A high incidence of onchocerciasis is found in the valleys of the Rivers Niara, Ashva, Nkusi and others that descend from the central African plateau 1,200 to 1,500 meters above sea level. In some valleys almost the whole population is infected. In the valley of the River Niara, of 152 persons examined, microfilarie were found in 135 (88%). Among the adult population living at an altitude of 1,500, 1,200 to 1,350 and 1,000 feet above sea level, 65%, 90% to 100% and 60% to 73% respectively were found to be infected [211]. Onchocerciasis is found in children between two and three years of age (11.8%). Adults between 16 and 60 years and above (88% to 100%) are the most affected; males are more affected than females. Severe infections of onchocercal etiology are widespread.

In 1955, a pilot program for the control of the black fly was undertaken. The tributaries of four rivers were sprayed with larvicides. The flies vanished but after 18 months the sprayed areas were again full of the pests which could have flown in from neighboring valleys [300].

On the eastern slopes of the mountains bordering the Central African graben, *S. neavei* is present over a wide area. This is explained by favorable topographical conditions such as the presence of many rivers and rivulets congenial to black flies and their phoretic hosts, freshwater crabs. In the valleys of rivers descending the slopes of the mountains bordering Lake Albert some areas of onchocerciasis of type V are known. In the forests of Budong and Bugoma the vector *S. neavei* develops on crabs *P. loveni* in the small fast-flowing brooks and on *P. niloticus* and *P. johnstonei* in the larger, fast-flowing streams and rivers in the dense deciduous and evergreen intermittently humid forests [37]. The incidence of infection is 20% [37].

According to data obtained from examinations carried out in 1975 among people engaged in the lumber industry, 78% of the 250 workers in Budengo and 46% of the students of the school of forestry were infected with onchocerciasis [29]. In the period 1955-56 a campaign to control the vector was undertaken in this area, covering 256 square kilometers, as a result of which the vector stopped breeding and no new cases of the disease have yet been reported [9].

In the forest region of Bugoma onchocerciasis does not as yet pose a serious threat and no steps against the black fly have been taken [300].

In the western part of the country onchocerciasis is widespread in the valleys of rivers flowing from the slopes of Ruwenzari Mountain. Areas of onchocerciasis of type V are known in Bugoie and Bakonzho [86]. The main vector is S. neavei, though S. damnosum is also occasionally found. Larvae of S. neavei develop on crabs P. johnstonei, in the gallery forests at an altitude of 1,050 to 1,350 meters above sea level [296]. S. damnosum lives at somewhat lower altitudes in the valleys of the rivers descending the eastern and southern slopes.

Breeding places of S. damnosum are known in the valleys of the Rivers Ruimi and N'yanamasagani. The black fly S. damnosum is found in particularly large numbers in the dam zone near the city of Fort Portal in the valley of the River Mubuku at an altitude of 1,050 meters above sea level [296]. In 1958, of 383 S. damnosum studied 6.7% were found to be infected with O. volvulus [296].

A pocket of onchocerciasis in Bugoie is to be found on the eastern slopes of the mountain in the thickly forested valleys of the River Mubuku and its tributaries (the Kitazhuka and others) at an altitude of 1,020 to 1,230 meters above sea level. In Bugoie, of 230 people examined onchocercal infections were found in 54.4%. In 1958, skin biopsies of 728 people were taken, 91% of which gave positive results [296]. Onchocercal eye infections are also widespread. In Bukonzho 90% of 700 inhabitants examined in 1961 had microfilarie [195]. Over the years many limited attempts to control these vectors have been made in this region.

An area of onchocerciasis of type V is also known on the slopes of the mountains bordering Lake Edward. Of 1,847 local inhabitants examined in 1958, 67% were infected and blindness was found in 4.7% [29, 86].

In the eastern part of Uganda the black fly *S. neavei* is found in large numbers in the banana and coffee plantations on the south and south-western slopes of Mount Elgon in the valleys of the Rivers Malakasi, Lvakaka, Lilima, Manafva, N'yakirira, Namatala and others, on an area of 1,500 square kilometers [29]. Larvae of *S. neavei* develop on crabs *P. loveni* and *P. granviki*. More than 50% *P. granviki* collected from the River Namatala and 70% from the River N'yakirira carried larvae and pupae of *S. neavei* [29]. The density of *S. neavei* in the valleys of the Rivers Namatala and Manafva is as high as 25% [37]. According to data published in 1958 80% to 90% of the population in this area was infected [29]. Few flies are found on the western slopes of the mountain, which are covered by dense forest.

Attempts to control this vector made in 1957 achieved only a temporary reduction in their numbers. Complete eradication of the vector was not possible.

SUDAN: (See map, Fig.5). The first cases of the disease were registered in 1932 in Sudan [125, 147]. Areas of onchocerciasis are known along the River Nile and its tributaries. There is also a small pocket of onchocerciasis of type III on the River Nile in Juba.

In the middle reaches of the Nile (from Khartoum to Wadi Halfa) six large dams have been built. Though the river flows through desert, due to intrazonal conditions, *S. damnosum* are able to breed even as far north as 22° latitude (up to the second dam near the city of Wadi Halfa) [118, 176]. This city is the northernmost point where *S. damnosum* is found in Africa. Areas of onchocerciasis along the River Nile are found only to 19° latitude north (between the sixth and fourth dams). Two meso-endemic areas of type IV are found in Khartoum and Abu Hamed.

Abu Hamed is the northernmost area of onchocerciasis in Africa. Though *S. damnosum* had been known in this region for more than 100 years, until 1956 no case of onchocercal infection was registered in this city. In 1956, examination of the local inhabitants was conducted. Of 70 people examined, 35 (50%) had clinical signs of onchocerciasis and 23 (30%) had eye infections of onchocercal etiology [209]. None of them had ever left Abu Hamed. It is presumed that the disease was carried from the province of Bahr-Ghazal [209].

In this province and in Equatoria, the black fly *S. damnosum* and onchocercal infections are found in the valleys of the left-hand tributaries of the Nile draining an area of more than 40,000 square kilometers.

In the period 1930 to 1940 the incidence of infection among the people of this region was insignificant. Between 1948 and 1950 it increased and the disease extended to new areas [125]. The inhabitants have been known to leave these fertile lands out of fear of contracting onchocerciasis and as a result the population of Bahr-Ghazal has greatly diminished [125, 133].

At present the disease is widespread in the valley of the River Sue and its tributaries and also along the Rivers Tonj, Maridi, Olo, Aei and others (areas of type II). In the valleys of these rivers the incidence of infection among the population is generally as high as 80% to 90%. Onchocercal eye infections, according to data published in 1962, were found in 60% of cases, blindness in 5.6% and in some places in 10% [9, 133]. Adenopathy and genital elephantiasis are also widespread [148].

On the right-hand bank of the Nile the black fly *S. damnosum* and onchocerciasis are found in the valleys of the tributaries Sobat, Pibor, Akoba, Gila and Baro (province of Upper Nile) [148]. Onchocerciasis has been registered in the towns of Pibor Post, Kigille, Daga Post, Nadessa, Bagessa and others [36, 125] with an incidence of infection among the population of 30%. Subcutaneous onchocercal nodules and eye infections are widespread. A complete investigation of the territory has not yet been carried out. Missionaries have noted many cases of blindness and epilepsy. Blindness was found in 1% to 10% of the persons examined.

To the north of Daga Post, along the Sudan-Ethiopia border, little of significance is known about the presence of onchocerciasis [125]. In this area both *S. damnosum* and *S. neavei* are found. The former predominate [118]. Their breeding places have been found on the Blue Nile and its tributaries, the Dinder, Rehad, Didessa and Atbara in the provinces of Kassala and Blue Nile [118, 125, 261]. This part of Sudan is thinly populated but there are many cattle grazing in the area and the black fly feeds on them. At present there is no incidence of infection here but when the area is reclaimed it may appear [135].

ETHIOPIA: (See map, Fig. 5). Areas of onchocerciasis of type IV are known in the valleys of the tributaries of the White and Blue Nile, the River

Didessa (in the subprovince of Lekemti, in the province of Wallega) and the River Baro (in the subprovince of Gambela and Gore in the province of Illubabor), and also in the valley of the River Omo (and its tributaries, the Giby, Little Gibby, Gabie, Gojab and Gimir) (in the subprovince of Jimma in the Province of Kafa) [118, 261]. Onchocercal areas are situated at an altitude of 300 to 1,600 meters above sea level, in the shrub and thorn forests where the vegetation is without leaves in the dry months of the year.

According to data published in 1967, during a spot-check of 1,087 patients (765 males and 322 females) in the city of Jimma onchocerciasis was found in 28.2% males and 4.7% females. In children under 10 the disease was not found. Blindness brought about by onchocerciasis was very rare. Eye infections were found in only 23 (7.7%) of 300 patients examined; moreover, in only four cases could they be traced to onchocercal etiology. Elephantiasis was found in 15 patients (elephantine scrotum) [218].

2.6.4.2. AREAS OF ONCHOCERCIASIS IN THE BASINS OF RIVERS EMPTYING INTO LAKE VICTORIA

KENYA: (See map, Fig.4). The disease was first registered in Kenya in 1921 [128]. Up to 1955 areas of onchocerciasis of type V were known to exist in the provinces of Nyanza, Kodera, Kaimosi, Kakamega, Ngoina, Riana and Kudzha. The first two areas were hyperendemic with a very high concentration of the vector (from 200 to 300 *S. neavei* per man in one hour). In Kodera and Kaimosa, covering an area of 690 square kilometers, almost the whole adult population was infected with onchocerciasis. In 1940, 44,000 people were exposed to the risk of of infection in these areas. The other areas were mesoendemic with a smaller concentration of vectors (15.6 per man in one hour). In these endemic regions the inhabitants of the valleys where the rivers are very fast-flowing were particularly severely affected by onchocerciasis. These rivers are the Kitare and Sondu in Kodera, and the Yala and Nzoya, Diany and Kudzhi in Kaimosi and Kakamega. Eye infections of onchocercal etiology among the infected people were widespread. The valleys of these rivers were called "valleys of the blind".

From 1943 through 1955, in all six areas, larvicides against the vector were used with good results. The black fly S. neavei was completely eradicated from Kodera and Riana in 1946, from Kudzhi in 1952, from Ngoina in 1953 and from Kakamega and Kaimosa in 1955; they have not been seen since. At the present time, S. neavei is found in only two river valleys in Kenya at the foot of Mt. Elgon along the border with Uganda. The numbers of black fly are not large. Onchocerciasis is not found among the local inhabitants.

After eradicating the vector and preventing the transmission of the disease in Kodera, parasitological examinations of the inhabitants were carried out twice, in 1953 and 1957 [94, 212]. It was found that not one child born after these steps were taken in 1946 had onchocerciasis. The numbers of infected adults decreased gradually. However, in 1957, (11 years after checking transmission), onchocerciasis was still a major disease in Kodera. No fewer than 76% of the adult population above 20 years had skin infections of onchocercal etiology and progressive eye infections; 50% had subcutaneous onchocercal nodules [212]. Live microfilarie and adult helminths were found in the patients.

In the period 1963-64 another clinical, parasitological and ophthalmological examination was carried out on the inhabitants of Kodera, Kakamega, Maimosa and Ngoina with the idea of determining how much time is required for the disease to die out and how onchocerciasis survives in conditions where reinfection is ruled out. Examinations were carried out on 2,103 inhabitants.

In Kodera, where transmission of onchocerciasis had been checked 18 years before, no microfilarie or mature onchocerca were found. All the dissected nodules contained dead helminths [16]. In Kakamega, Kaimosi and Ngoina, where transmission had been checked nine and 11 years respectively before this examination, live onchocerca and microfilarie were found in the patients. A gradual reduction in the number of infected adults was observed. In many patients, blindness of onchocercal etiology developed a number of years after transmission was checked. It was concluded that O. volvulus preserves its capacity to breed for 13 to 17 years. During this period onchocerciasis continues to be a major source of infection. When the vector is still present reinfection is still possible but the infection gradually regresses until it completely disappears.

2.6.4.3. AREAS OF ONCHOCERCIASIS IN THE BASINS OF RIVERS EMPTYING INTO THE INDIAN OCEAN

TANZANIA: (See map, Fig. 4). The disease was first registered in Tanzania in 1942 [126]. Two small pockets of onchocerciasis of type IV are known on the east side of Mount Usambara (Tanga region) and in the mountains of the Marogoro region. In the former region, onchocerciasis has been registered since 1961 [298]. Infected people are found on the eastern slopes of Mount Usambara in the valleys of the Rivers Ziga and Amana at an altitude of 360 to 810 meters above sea level. In 1966, 260 males and 130 females were examined in this region. Approximately 30% of the inhabitants were found to be infected with onchocerciasis [298]. Eye infections were also found. Of 88 people who were very thoroughly examined, 83.3% had microfilarie in the skin, 48.8% had subcutaneous onchocercal nodules and 23.8% had eye infections [298]. The highest incidence of infection was found in the towns of Mkhesa (60.7%), Msasa (48.0%), Khemka (45.7%), Kisivani (44.0%), Leva Bulva and others (43.1%) [298].

The area of onchocerciasis in the hilly region of Morogoro is the southernmost in East Africa. During the period 1942-46, 686 cases of onchocerciasis were registered here [126]. In 1965 an entomological survey of the region was carried out for the first time; 18 species of the black fly were found, including S. damnosum. The largest number of patients are found in the regions of Sali and Ruakhi in the basin of the River Rufiji [126]. The incidence of infection among the population of Sali in 1965 was 87% (125 examined) and in Ruakhi it was 71% (60 examined). Severe eye infections have been recorded. On the average, 30% of the adult population in this endemic region was found to be infected. The few children examined did not show onchocerciasis [56].

2.6.5. NORTH AFRICA

TUNISIA: The only known case of onchocerciasis in Africa outside the tropical belt was registered in 1926 in the port of La Lulett. Cutaneous investigation revealed fragments of a mature nematode of genus Onchocerca (Diesing, 1841) and microfilarie in the connective tissue of the patient.

The causative organism was not determined. Authors suggest that it could have been onchocerca of domestic animals (_O. guttorosa_, _O. gibsoni_, _O. reticulata_, _O. cervicalis_) [24]. A species of black fly found in this region is not known to be a vector of onchocerciasis in the endemic regions of tropical Africa. Onchocerciasis in horned cattle and horses is known in this region.

A second hypothesis put forward was that the causative organism could have been carried into the country by Senegalese soldiers temporarily stationed there [24]. Not a single case of onchocerciasis has since been recorded.

2.7. REASONS FOR AND PATTERN OF DISTRIBUTION OF ONCHOCERCIASIS IN AFRICA

Onchocerciasis is more widely distributed in West and Central Africa than in East Africa. To a great extent this is explained by the natural conditions favorable to the survival of the vector and the development of the causative organism it harbors up to the infective stage. An important factor in the survival of the vectors of onchocerciasis in Africa is the presence of rivers having permanent drainage. The river network map of Africa corresponds to the rainfall map in respect of basic characteristics. The amount of rainfall and its distribution throughout the year determines the latitude limits of the black fly in Africa. The amount of rainfall determines the drainage of the river networks and subsequently the presence or absence of the black fly vector and the geographical and regional peculiarities of the epidemiology of the disease.

The tropical rain forests, the park-like, deciduous and evergreen seasonally humid forests and the tall-grass savanna, some of which receive 1,200 to 1,700 mm of rain a year, uniformly distributed, have a many-branched, dense hydrographical network with permanent drainage. This is the most favorable natural prerequisite for perennial survival of the black fly.

In the typical park and desert savannas and shrub and thorn forests which have an annual rainfall of 500 to 1,200 mm and a prolonged dry season of five to nine months the river network is much less dense. Some of the rivers have seasonal drainage. The breeding places of the fly in these zones are found mainly in the more humid parts (having an annual rainfall of 800 to 1,200 mm) and are very sparsely scattered in the drier areas (having an annual rainfall of 500 to 800 mm). On rivers with seasonal drainage the bed dries up for nine months of the year. This leads to the shrivelling of the eggs and non-development of larvae of S. damnosum and to a complete absence of mature insects.

In the arid and semi-arid regions of northern and southern Africa, with an annual rainfall not exceeding 500 mm and few rivers or a complete absence of surface drainage, the natural prerequisites for the breeding of the black fly are non-existent. The only exception to this is the Nile valley, where the natural conditions are quite different from other desert regions.

So the latitude limits of the black fly are determined by the quantity of rain received and the relative humidity of the air. The isohyet of 500 mm annual rainfall can be considered the latitude limit of the black fly vectors of onchocerciasis in Africa (see Fig. 1).

The northern boundary of the distribution of the black fly passes through an arc of 15° latitude north in the basin of the River Senegal (Mali); 14°5' latitude north along the western arch of the River Niger and 12°40' latitude north along the eastern arch; 12°18' latitude north in the basin of the tributaries of the Niger in western Nigeria and 11° latitude north in eastern Nigeria; 9° latitude north in the basin of the River Chari (Chad); 6° to 9° latitude north in the basin of the River Bahr-el-Ghazal (Sudan) and 9° to 10° latitude north in the basins of the River Omo and tributaries of the River Nile (Ethiopia).

Only in the valley of the River Nile, with its intrazonal natural conditions, are breeding places of the black fly S. damnosum found as far as 22° latitude north in Wadi Halfa, which is the northernmost outpost of this species in Africa.

The southern boundary of the black fly vector passed through 13° latitude south in the basin of the River Cuanza in Angola and 8° latitude south in the basin of the River Rufiji in Tanzania. The altitude limits of the black fly are dependent on a number of factors. In the hilly regions, apart from the altitude, the quantity of oxygen in the water is reduced, which is not favorable to the existence of larvae of S. damnosum and is possibly a limiting factor. The number of black flies S. damnosum in the hills is always considerably lower than in the plains. The lower air temperature is certainly another determining factor. The lower temperature limit for the black fly has not quite been determined. As has been indicated, the black fly S. damnosum can be active at a temperature of 18°C. An air temperature lower than 18°C restricts the distribution of the black fly. Black flies S. damnosum are found up to an altitude of 1,800 meters and S. neavei up to 2,100 meters above sea level.

Within the boundaries of its potential habitat the black fly is distributed very unevenly. The central point of the vector's area is determined by the presence of fast-flowing rivers offering suitable breeding places. Such areas in the river valleys are usually confined to places where there is an outcrop of granitic bedrock foundations and rocks.

The area of onchocerciasis in Africa is smaller than the area covered by the vector. As already stated, the causative organism of the disease develops in the black fly up to the infective stage at air temperatures not lower than 21° C.

The latitude limit of the distribution of onchocerciasis in Africa is perhaps determined by an isotherm of 20° C in the midwinter month (January) in the northern hemisphere and July in the southern hemisphere. All the areas of onchocerciasis, as can be clearly seen from Fig. 6 (appendix) are concentrated in territory having an average monthly temperature of more than 20° C throughout the year.

The northern boundary of onchocerciasis corresponds to the northern boundary of the distribution of the vector, which is facilitated by lower rainfall and humidity of the air (15° latitude north in the western part of the continent and 10° latitude north in the eastern part). So far as temperature conditions are concerned, onchocerciasis could move further north. It is not able to do so owing to the absence of the vector. Only in the valley of the Nile is the boundary of onchocerciasis as far north as 19° latitude. Further progress of the disease toward the north (the vector has been found at 22° latitude north) is limited by temperature conditions: in January, the midwinter month of the northern hemisphere the 20° isotherm runs along the 19th parellel.

The southern boundary of distribution of onchocerciasis in the western part of the continent runs along 13° latitude south in the basin of the River Cuanza (Angola) and corresponds to the southern boundary of distribution of the vector; and along 8° latitude south in the basin of the River Rufiji (Tanzania) in the eastern part of the continent.

So the area of onchocerciasis is between 15° latitude north and 13° latitude south in the western part of the African continent and between 10° latitude and 8° latitude south in the eastern part.

The altitude limit of the distribution of onchocerciasis is determined by the mean monthly air temperature necessary for the development of the causative organism. It lies at an altitude of 1,200 to 1,400 meters above sea level.

In rare cases onchocerciasis occurs as much as 1,600 meters above sea level. Most of the known areas of onchocerciasis in West Africa are situated at an altitude of 200 to 600 meters (usually 400 to 600 meters), in Central Africa, at 480 to 600 meters above sea level [31, 86, 114].

Within the boundaries of the area of _S_. _neavei_, pockets of onchocerciasis are known in places at the following altitudes, 800 m (Sankuru and Lubilash in Congo, Kinshasa); 1,134 m (areas in Uganda and Kenya around Lake Victoria); 1,250 m (in the area around Mt. Ruwenzori in Uganda); 1,600 m (on the slopes of the mountains bordering Lake Edward in Uganda), etc.

In several countries of Africa with highlands 1,200 to 1,400 m above sea level, where the vectors of the disease are known, the causative organism has not been identified and onchocerciasis is not present among the local inhabitants. These countries are Zambia, Southern Rhodesia, Somali Republic, Mozambique, Republic of South Africa, Rwanda an Burundi (vector S. damnosum); Zambia, Malawi, Republic of South Africa (Natal) (vector S. neavei).

Regarding these countries, Meillon suggested that either the causative organism is not known in these regions or it has been introduced but has not taken root owing to unfavorable natural conditions [202]. The second suggestion is more probably correct because in the hills of East Africa the temperature is such that the causative organism of onchocerciasis could hardly take root. In these countries the black fly vector ceases to be anthropophilic and shows no aggressiveness toward man. Mammals and birds serve as their hosts for feeding purposes [81, 82, 83, 84, 86].

Black flies S. damnosum not aggressive toward man have often been collected in the hilly region of Congo (Kinshasa), in Kivu, at 1,400 m above sea level, along the upper reaches of the River Ituri, at 1,700 to 1,750 m , and on the banks of the Lake Kuru in Bukavu, at 1,500 m [81]. Cases of onchocercal invasion in the inhabitants of these regions are not known.

In thorough examinations carried out on 389 inhabitants living at 1,465 to 2,000 m above sea level in the Luiro region (Congo, Kinshasa), microfilarie of O. volvulus were identified in only three. It was discovered that the infection had not been picked up locally but at the time of trips to endemic regions at lower altitudes [71].

In Katanga, which is 1,500 to 1,700 m above sea level, all the cases of onchocerciasis among the inhabitants living in the valleys of the Rivers Lualaba and Lukuga have been imported from outside [86]. In spite of these cases of onchocerciasis among the local population, the vector of the black fly *S. damnosum* is not found around the city of Lubumbashi (Congo, Kinshasa) or in Zambia in the Luapula River and Lake Mweru regions which have a common border with Katanga province [86, 231, 290, 293]. Onchocerciasis is not known either on the high plateau of Rwanda and Burundi 1,600 to 1,700 m above sea level in spite of the fact that the black fly *S. damnosum* of many types have been collected on the Rivers Akanuaru, Ruvuvu, Gokoma, Mvogo, Taroko, Vase and others. In this region, *S. damnosum* shows no aggression toward man [82].

In other countries of Africa too (Uganda, Republic of South Africa; Transvaal) which are 1,400 m above sea level the hosts of the black fly *S. damnosum* are mammals and birds [82, 86, 98]. In the hilly regions the black fly *S. damnosum*, which feeds on the blood of animals, is a vector of other types of onchocerca, including that of horned cattle [87, 105]. In the hilly regions of Rwanda, Burundi and Kivu (Congo, Kinshasa), 40% of cattle are infected with *O. guttorosa* [87, 105].

It is presumed that at altitudes of more than 1,400 m above sea level the black fly *S. neavei*, like *S. damnosum*, feeds on the blood of animals and is a vector of other species of filaria including *O. guttorosa* [86]. In such regions onchocerciasis in man has not been registered.

Thus, the distribution of onchocerciasis is possible mainly in regions having a warm and humid climate, situated not more than 1,200 to 1,400 m above sea level. Only in these areas is the causative organism of the disease able to develop to the invading stage and become a threat to the human inhabitants. It has all the conditions favoring manifestation and stabilization of invasion.

However, the natural prerequisites for the existence of onchocerca in human beings are not the same in every landscape zone. The tropical rain forest, the park-like deciduous and evergreen, seasonally humid forests and the tall grass savanna zones have favorable prerequisites for the development and wide dissemination of onchocerciasis. In the typical and park savanna, the disease has taken root mainly in the wetter parts having an annual rainfall of 800 to 1,200 mm.

In areas where there are rivers with permanent drainage transmission is possible throughout the year and these are endemic territories. In areas where the rivers are dry for some months of the year transmission is possible only in the rainy season. In the drier parts of the typical and park savanna, desert savanna and shrub and thorn forest zones with an annual rainfall of 500 mm and with a prolonged dry season of eight to nine months, the endemic nature of the territory is not established owing to the unfavorable conditions for the vector. Transmission of onchocerciasis is very much a seasonal occurrence and is possible only for a short period of three to four months when it rains.

Large areas of onchocerciasis are formed by natural as well as ecological factors. The building of irrigation systems and hydroelectric stations which are important for the development of the agriculture and industry of developing countries leads to an increase in the number of breeding places of the vector (on the spillways of dams). The result is the creation of new areas of the disease and a rise in the incidence of infection among the population. The area of the disease is thus extended. Distribution of onchocerciasis can also be attributed to laborers being recruited from other endemic areas to take part in this construction activity. They carry the disease to these new areas where it was not previously known [9].

Onchocerciasis has an unfavorable effect on the economy and development of many countries of Africa. In so far as it affects the economies of the countries situated in endemic regions it may be termed a social disease [190].

Wide distribution of onchocerciasis hinders the completion of many projects which could be undertaken for the development of irrigation, agriculture and forestry.

In endemic areas of Africa, the cost of constructing industrial or other projects is high owing to many workers being affected by onchocerciasis and having to be treated [9]. The fear of blindness also causes difficulties in finding personnel and leads to the desertion of employees after short spells of work. The severe attacks of the black fly greatly reduce the working ability of the people. Often the inhabitants of regions where onchocerciasis is particularly widespread leave en masse, deserting the fertile lands. Large territories become void of human habitation. In endemic regions the constant risk of infection to which the people are exposed compels developing countries to spend large sums on the control of the disease.

In the countries of Africa situated in the endemic region, during the construction of water-supply systems and hydroelectric stations and the development of plantations and forest production units, large resources have to be devoted to control the vector of onchocerciasis.

During the construction of the Kandzhi hydroelectric station on the River Niger in Nigeria, according to WHO data, an extra US $ 100,000 had to be spent every year to protect the laborers from attacks by the black fly and infection by onchocerciasis [9].

The fight against the vector of onchocerciasis is being carried out in almost all countries in the endemic region of Africa but with poor results.

Complete eradication of the black fly has been possible only in isolated pockets. Elsewhere it has been only temporary owing to the rapid restoration of the numbers of the vector, which flies in from nearby unsprayed areas.

3. ONCHOCERCIASIS IN THE COUNTRIES OF LATIN AMERICA

In Latin America onchocerciasis is widely distributed in three countries—Mexico, Guatemala and Venezuela.

In 1965, the first case of the disease was registered in Colombia. Isolated cases of the disease have been registered in other Latin American countries, in Costa Rica (in the region of the city of Limon) [6, 7, 9], in Dutch Guyana (Surinam) [45, 124, 261], in Guyana [217, 261], in French Guyana [217, 261], in Argentina [217], in Equador [45], on the Antilles [217], and in Brazil [6, 7, 9]. Regarding the distribution of onchocerciasis in Brazil, there is no one opinion. Dobrovol'skii-Yu, Kassirskii, Plotinikov [8] and Leikina [11] think there are areas of onchocerciasis in Brazil whereas Lysenko and co-authors [13] indicate that at present there are none and that the causative organism of the disease had undoubtedly been imported but had not taken root.

3.1. VECTORS OF ONCHOCERCIASIS

In Mexico and Guatemala the disease is transmitted by *Simulium ochraceum* (Walker, 1860), *S. metallicum* (Bellardi) (synonym *S. avicum* — Hoffman, 1930) and *S. callidum* (Dyar and Shannon) (synonym: *S. mooseri* Damf, 1927). -The black fly *S. ochraceum* is the main vector of onchocerciasis in Latin America. Two other species play a secondary role in transmitting the disease: they have less contact with man [23, 277]. In a few areas, *S. gonzaleri*, *S. haematopotum* and *S. veracruzanum* [277] are the vectors of onchocerciasis.

In Venezuela the black fly species *S. metallicum* and *S. exigum* (Roubaud) transmit the infection. The former is the main vector [107, 183, 229]. *S. exigum* acts as a vector of onchocerciasis in a limited area near big rivers where it is found in large numbers [183].

In Colombia, the black fly *S. exigum* is the only vector of onchocerciasis. It is assumed that in Venezuela and Colombia the black fly *S. ochraceum* is the vector [107]. The role that the black fly *S. callidum* plays in the transmission of the disease was first determined in 1930 by Hoffman and that of *S. ochraceum* and *S. metallicum* by Strong in 1931 [23]. In 1949, in Mexico, Vargas and Ruic Reies reported transmission of onchocerciasis by *S. exigum* and in 1952, in Guatemala, Gibson and Dalmat identified the potential vectors *S. haematopotum*, *S. veracruzanum* and *S. gonzaleri* [193, 227].

In Mexico and Guatemala the vectors of onchocerciasis are distributed on the slopes of the Sierra Madre mountain range and in Venezuela and Colombia on the slopes of the Cordillera ranges.

3.1.1. ECOLOGY OF THE VECTORS

3.1.1.1. LARVAL STAGE

In the hills of Latin America the black fly zones are markedly vertical. They are distributed in three belts whose Spanish names have been adopted in Russian geographical writing. These are the *tierra callente* (hot region), *tierra templada* (temperate region) and *tierra fria* (cold region) ranging from 10 to 2,700 m above sea level. *S. ochraceum* lives at altitudes of 150 to 2,400 m above sea level, mainly from 900 to 1,500 m ; *S. metallicum* from 10 to 2,700 m. but mainly 600 to 1,500 m ; and *S. callidum* from 270 to 2,460 m but mainly from 270 to 1,800 m [45]. The black fly *S. callidum* prefers the higher regions. *S. metallicum* and *S. callidum* prefer rather lower areas. *S. exigum* also are usually found in the lower areas. *S. gonzaleri* and *S. haematopotum* are distributed at altitudes of 1,000 to 1,500 m above sea level and *S. veracruzanum*, from 1,300 to 2,000 m [45] (Fig. 7).

Fig. 7. Altitude distribution of the breeding places of vectors of onchocerciasis in Mexico [276, 277].

Key 1) Height in meters above sea level.

2) Boundaries of transmission of *O. volvulus*

In Venezuela and Colombia the vectors of onchocerciasis are distributed at altitudes of 200 to 1,300 m above sea level [183]. The vectors of onchocerciasis in Latin America breed in the many fast-flowing streams and river tributaries pouring down the slopes of the Sierra Madre and Cordillera, which are covered by equatorial forests.

Table 2. Characteristics of breeding places of vectors of onchocerciasis in Guatemala [45].

	S. ochraceum	*S. metallicum*	*S. callidum*
Width of flow, cm	2.54-150	2.54-240	30-450
Depth of flow, cm	2.54-150	Less than 30	Less than 30
Velocity of flow, cm/sec	2.5-25.4	2.54-50.8	2.54-76.2

The main vector, the black fly *S. ochraceum*, always breeds in small flows, in a limited area, in cold, clear water. Its breeding place is usually near living quarters on coffee plantations. *S. metallicum* also breeds mainly in small flows but *S. callidum* and *S. exigum* generally breed in large rivers, though sometimes in small flows as well and in both sunny and shady places [45].

S. metallicum and *S. callidum* adapt to different types of breeding places better than other species. *S. ochraceum*, *S. metallicum* and *S. callidum* in Mexico and Guatemala reproduce throughout the year, but mostly in the dry, winter months (from September/October to March/April) when the number of mature insects reaches its maximum.

Winter, i.e. January to March [144], is the breeding period of the black fly in Venezuela.

The numbers of the black fly *S. ochraceum* in Mexico and Guatemala are at their highest twice a year; in January, in the middle of the dry season and in August in the middle of the rainy season, though they are fewer then than in the dry season [154]. For *S. metallicum* these peaks, though less pronounced, occur in March and June and for *S. callidum*, in January/February and in the middle of August [154].

In the dry season when the streams have less water and carry less floating material, the temperature of the water is lower. This offers the most favorable conditions for the breeding of the black fly [275].

In the rainy season (April to September) leaves and branches are carried along the turbulent rivers, which become too swift for the larvae: they are washed away and destroyed [183, 276].

Large quantities of organic material in the rivers and increased water temperatures in the warm rainy season lower the oxygen content of the water, which also unfavorably affects the aquatic stages of the vector. Rain renders the water muddy, which makes feeding difficult for the larvae [274].

This destruction of larvae in the rainy season leads to a decrease in the numbers of mature insects.

The larvae of these species are fairly resistant to changes in the acidity or alkalinity of water [276].

The egg deposition of the American species of the vector continues for five days. It takes place in the afternoon and continues until nightfall [276]. The larva (depending on the species and nutrition, etc.) takes from 23 to 44 days to develop and the pupa, five days [270, 276, 277].

The larvae of the black fly are rheophilic and attach themselves to the wet substrata in the rivers such as the leaves and stems of plants and vegetable waste and stones.

They feed on bacteria, particles of higher species of vegetation, weeds, the simplest monocellular organisms and copepoda and crustalea [273].

3.1.1.2. IMAGO STAGE

The American species of the vector require the same external environmental conditions as those of Africa. They need relatively high air humidity, moderately high temperatures without excessive humidity and fairly dense vegetative cover.

The largest numbers of the black fly and greatest density are found in the high central belt of *tierra templada*, whose boundaries pass over an altitude of 600 to 800 and 1,600 to 2,000 m above sea level. In the onchocercal zone in the state of Chiapas (Mexico), which is 600 to 1,200 m above sea level, the average annual temperature is 25°C to 28°C with a maximum of 36°C to 38°C and a minimum of 10°C to 17°C [273]. Daily and seasonal variations of temperature are less pronounced. Annual rainfall is 2,900 to 3,200 m [273].

In the *tierra templada* belt, the abundant vegetative cover provides a very favorable environment for the black fly. This happens to be the main coffee-producing area of Latin America. The growing of coffee necessitates the planting of thin forests of specially selected shade-providing trees. The vegetative cover thus provided and the high humidity as well as the uniform temperatures are very favorable to the black **fly**.

In the *tierra callente* with its torrid, very humid climate and thick equatorial forests and in the *tierra fria* with its cold climate and great variations in temperature, the number of black flies is insignificant.

With respect to the gonotrophic characteristics of the black fly, American authors divide these vectors of onchocerciasis into two groups, viz. an autogenous group which needs blood for the first gonotrophic cycle and an autogenous group whose larval stores of nutrition are sufficient to carry them through the first gonotrophic cycle, which they are able to complete without feeding on blood. The females attack man, birds and mammals to suck blood [277].

3.2. SIMULIDAE AS VECTORS OF ONCHOCERCIASIS

The flight range of labelled female vectors in Guatemala has been recorded by Dalmat [65] as 15.5 km. He found that it was considerably less in infected females. As is true of *S. neavei* in Africa, the distribution of American vectors over a territory is generally linear, along the banks of hill rivers, under vegetative cover. Their radial flight distances are insignificant, even in the rainy season.

The life-span of the American vector is greater than that of the African vector. It is presumed that the life-span of the female vector in Mexico is from 20 to 90 days. In Guatemala it is 85 days. However, Vargas [276, 277] observed that these evaluations have not been made in relation to any single species of black fly. The life-span of the black fly in Mexico varies a great deal, depending on the season of the year, meteorological conditions, etc. It is longer in the dry season than in the wet season [276, 277].

Under optimal conditions, the vectors in the dry season (from October to the end of March) in Mexico and Guatemala produce five generations in a period of 182 days [270, 276].

The life-span of females infected with O. volvulus is considerably shorter. Many of them die within the first four days of being infected [45]. The degree of infection of the female vector of onchocerciasis in the Americas is lower than that of her ounterpart in Africa. The degree of infection of the main vector, S. ochraceum, in Guatemala is estimated at 2.5% [45, 236]; of S. metallicum in Guatemala, at 0.9% and in Venezuela, at 3.8% [45, 183].

The epidemiological activity of the vector, on the whole, is high. Their long life-span and accordingly the large number of gonotrophic cycles they complete, short flights and almost permanent concentrations in the breeding places, their close contact with people permanently living in the coffee plantation area and the seasonal influx of laborers in the dry season to pick the berries, facilitates active transmission of onchocerciasis.

In Mexico and Guatemala transmission of the disease takes place mainly in the dry season (October through April), which coincides with the seasonal migration of temporary labor and the large numbers and hectic activity of the vectors in this period.

3.3. HOW THE FEMALE VECTOR ATTACKS AND INFECTS MAN WITH ONCHOCERCIASIS

In Mexico and Guatemala the species of *S. ochraceum* is very anthropophilic and 88.3% of all the flies that attack man in the rainy season and 86.5% in the dry season are of this species [213].

S. metallicum is moderately anthropophilic. It attacks horses, mules, donkeys, dogs, cats [154] and man. Of those attacking man, *S. metallicum* constitutes 3.24% in the rainy season and 7.36% in the dry season [213].

S. callidum constitures 8.43% in the dry season and 6.11% in the rainy season. [213].

The most zoophilic of the species are *S. exigum*, *S. veracruzanum* and *S. haematopotum*, which feed on animal blood and rarely on human beings and play only a secondary role in the transmission of onchocerciasis [154]. The greatest activity among the black flies is observed from sunrise, between seven and ten o'clock, and in the afternoon, between one and eight o'clock [276, 277].

Ultraviolet rays activate the black flies and the red rays of sunlight paralyze their movements [271]. In the rainy season their morning collection is 48.6% of the whole and in the latter half of the day 51.39%. In the dry season the black flies are more abundant in the mornings (the collection is 58.4% and 41.58% respectively). [213].

In the rainy season the black fly *S. ochraceum*, is abundant in the first as well as in the second half of the day, whereas *S. metallicum* and *S. callidum* predominate in the morning hours. In the dry season *S.*

ochraceum predominate in the morning hours whereas *S. callidum* are found in equal numbers in the first and second halves of the day [213].

In the rainy season (April to September), when there are strong winds and high humidity, the activity of the black fly diminishes. The number of bites increases during the change of season and during the fall in barometric pressure. On windy days the black fly attaches itself to the underside of leaves close to the ground.

In the dry season the activity of the flies greatly increases. Their bites are more frequent between December and February [272]. They stay in the tree-tops at night and at sunrise fly down to ground level.

The bites of *S. ochraceum* occur mainly on the upper part of the body, particularly on the head, because the flies fly at a height of more than one meter from the ground. The bites of *S. metallicum* in Mexico and Guatemala are not localized whereas in Venezuela they are found mainly on the lower part of the body [52, 154].

Village people suffer mostly from attacks by the black fly. Very rarely are city dwellers attacked.

Unlike the African species, the black flies of Mexico and Guatemala attack people in their houses but more often they are attacked while working out of doors [23]. Male and female are equally affected; adult patients predominate though the disease is found in children as well. Robles [235] observed the presence of onchocercal nodules in a three-month-old, breastfed baby and hard, isolated onchocercal nodules in breastfed children of four months of age [235].

In Mexico and Guatemala the disease is found mostly among Indians. In Venezuela and Colombia the Negro population is mostly affected by onchocerciasis.

3.3.1. CLINICAL MANIFESTATIONS OF THE DISEASE

The clinical manifestations of onchocerciasis in the countries of Latin America are different from those in Africa. In Latin America (Guatemala) one to six and a maximum of 24 nodules are found in infected people. Of these, 70% are on the head, mainly in the occipital region [14, 23, 52].

In America only skin and eye infections of onchocercal etiology are known. Of chronic skin infections, the following are most commonly found: dotted pigmentation of the skin of the upper portions of the body (and legs) and of the face, ('Erisipela-de-la-costa', 'Mal morado'). 'Livinoe litsoe' of the face is found only in Mexico and Guatemala.

Erisipela-de-la-costa is a particularly severe form of dermatitis (leading to inability to work) and is manifested in the form of erythema and edema of the skin in the region of the cheeks and forehead. It is accompanied by fever and ulceration of the infected region. 'Mal morado' is a skin exanthema of violet color, most commonly affecting the face and chest. 'Livinoe litsoe' is characterized by atrophy leading to flabbiness of the skin, particularly of the nose, lips and mandibular regions, which becomes wrinkled as a result. Among eye infections of onchocercal etiology in Latin America are the following: punctate keratitis, conjunctivitis and irridocyclitis [85]. Atrophy of the optic nerve is hardly ever found. Eye infections are found in 5% of the onchocercal patients in Guatemala and in 11.6% in Venezuela [236].

In Venezuela, the clinical picture of the disease differs from that in Mexico and Guatemala and is closer to the African form. It differs from the latter, however, in that in the majority of cases the disease is not severe and reinfections are rarely found.

3.4. BOUNDARIES AND TYPES OF AREAS OF ONCHOCERCIASIS

As in Africa, onchocerciasis is not distributed in a compact form but in pockets along the small hill rivers around the coffee plantations.

The boundaries of the disease are determined by the distance the infected females fly from their breeding place.

In respect of ecological peculiarities, the vectors of onchocerciasis in the countries of Latin America are closer to the African species S. neavei and the areas of onchocerciasis in Latin America are similar to those associated with this species in Africa.

3.5. AREAS OF ONCHOCERCIASIS IN THE COUNTRIES OF LATIN AMERICA

In Mexico, three areas of onchocerciasis are known; two in the State of Chiapas and one in the State of Oaxaca. Indians and Indo-mexicans living in small mountain habitations located on coffee plantations mostly suffer from onchocerciasis.

The first cases of infection were reported in 1923 [219]. In 1927, the Public Health Department conducted first investigations and collected data on clinical symptoms, biology and ecology of the causal organism and the vector. From 1929 in Mexico onchocerciasis was considered as one of the major problems of national health [219]. Two dispensaries have been opened to treat onchocerciasis patients in Iguale (State Oaxaca) and isla (State Chiapas).

According to the data of 1962 the number of persons suffering from onchocerciasis in Mexico was about 60,000 [192].

Onchocerciasis is most prominent on the territory of Sokonusko in the southern part of the State of Chiapas on the slopes of South Sierra Madre in the basin of the River Despoblado and Grichalva over an area of 6800 km^2. Boundary of the area is defined by 15°4' - 15°57' N and 92°5' - 93°7' W [90].

The third area passes over the Pacific slopes of South Sierra-Madre ; two-thirds on slopes facing the Gulf of Mexico. The endemic region of Sokonusko has an altitude of 50-2000 m above sea. The highest vector density and intensity of endemy are observed at an altitude from 500-1200 m above sea where 70% population has onchocerciasis infection.

To the east the Sokonusko area borders with Guatemala passing into the endemic zone of Wewetenango district.

In 1932 first studies were made in this area and it was shown that onchocerciasis patients are found in small settlements on coffee plantations. In 1944 the first register of onchocerciasis patients was prepared in the State of Chiapas which showed 22,580 patients (19.1% of the population examined) [219]; in 1954 the Sokonusko area had 27,163 patients suffering from onchocerciasis [207].

In 1962-1963, the endemic area had a population of 93,000, out of which 30,000 (32.2%) suffered from onchocerciasis [52, 90]. In the high-altitude belt of tierra templada, where ecological conditions were especially favorable for the vector, 80-98% population suffered from onchocerciasis infection. The average invasion of population in the Sokonusko area in 1962 was 49.95% (9889 patients) including 51.7% males and 47.8% females [90]. Adults, over 20 years in age were affected in 60% cases and children (1 - 4 years) in 17% cases.

The Sokonusko area has the largest coffee plantations in Mexico. During the harvesting period (October December) about 40,000 seasonal laborers work daily which come here from many areas of the country including the onchocerciasis free areas as well as bordering regions of Guatemala. The seasonal migration of labor has a great bearing on the spread of onchocerciasis to new areas. In the last 20 years an extension of the area of onchocerciasis around Sokonusko has been observed. On the Pacific Ocean, on the slopes of the Sierra Madre and in the towns of Mapastepek, Pikhikh'yapan and others, sister areas of onchocerciasis were formed [90]. There is a danger of a further expansion of the area taking place and of the formation of micro-areas in as yet uninfected territory.

Treatment of patients in the Sokonusko areas has been provided since 1932. In 1963, more than 70,000 people were covered by projects undertaken to fight the epidemiology of the disease in this area [207, 219]. Between 1954 and 1959, in the basin of the River Despoblada, anti-larval measures were taken [207]. Partial success was recorded in curtailing the breeding of new generations of the black fly. However, the density of the adult fly was not reduced much because the rivers and streams in the neighboring regions were not treated.

The second area, Chamula, situated in the central part of the State of Chiapas to the north of San Cristobal, was formed in the 1930s. This area is of secondary origin. The disease was brought in by inhabitants of the area who worked as seasonal laborers on the coffee plantations in Sokonusko. It is situated in the hilly mesa region of Sierra Sontenuits between 16°52' and 17°7' latitude north and 92°40' longitude west and covers an area of 700 sq km. [90]. This area is free of infection because of the unfavorable conditions for the vector in the adjacent region. The river network in the area is formed by the tributaries of the Rivers San Pablo and Catarina which debouch in the River Grijalva. In this area there are 70 villages in which 22,500 people live; of them 4,000 are affected by onchocerciasis (18.2%) [90]. Onchocercal nodules were reported in 7.76% of the people examined [53, 207]. In 1955 a campaign was launched against the vector and since 1959 mass treatment of patients has been provided [207].

The third area of onchocerciasis is situated in the State of Oaxaca, to the north of Ixtlan de Juarez, near the Sierra de Suares mountains on the eastern side of the Sierra Madre. Onchocerciasis is less prevalent in the hills, the endemic area being 17°25' and 17°48' latitude north and 96°12' and 96°40' longitude west, covering an area of 1,400 sq km. Here 45,000 inhabitants live of whom 5,800 suffer from onchocerciasis [52, 90]. In 53 villages in the most affected district of Ixtlan de Juarez, 25.8% of 6,767 examined were affected [208, 261]; in the district of Villa Alta, in 26 villages, 10% of 14,724 examined were affected; in Tutapek, in 26 villages, 6.8% of 6,535 examined were affected; in Kuikatlan, among 7,745 examined, 1.4% were found to be suffering from onchocerciasis [208].

As in the Sokonusko area in Oaxaca an extension of the boundaries of the endemic zone has been observed in the last few years as a result of the migration of local labor. New areas appeared in the district of Kuikatlan. In the eastern part of the zone also there are favorable conditions for expansion of the area of the disease.

Between 1949 and 1962 a campaign for the control of onchocerciasis was mounted in the State of Oaxaca. Since 1930 attempts had been made to control onchocerciasis in Mexico. The first counter epidemic measures were taken in the State of Chiapas. The disease is mainly being controlled by treating patients (surgical removal of onchocercal nodules and therapeutic treatment by Diethylcarbamazine, Hetrazane, Suramin, etc.) and by control of the vector. As a result of treatment, it has become possible to prevent new cases of blindness and to bring down the number of severe eye and skin infections considerably. The control of the vector is difficult due to the fact that its breeding places are situated in the many small hill streams which are sometimes no wider than two to five centimeters and cannot be sprayed with insecticides [45]. The city of Ixtlan de Juarez, in the hilly State of Oaxaca, is the center of operations from which the fight agianst onchocerciasis is being conducted.

GUATEMALA: The disease was first reported in this country in 1904 [164]. Onchocerciasis is widespread among people working on the coffee plantations on the southern and western slopes of the Sierra Madre range, bordering the Pacific Ocean between 14° and 15° latitude north. Of these two endemic zones, the western zone covers the districts of Huchuetenango, Chimal'tenango, Solola, Suchitepekes, Kesaitenango and Guatemala. The other, to the east, occupies the districts of Escuintla and Santa-Rosa. These two endemic zones appear isolated from each other though they are contiguous. Apart from these there is a small pocket of onchocerciasis in the district of Knutyapa in the municipality of San Jose Akatempa.

In 1918, in the endemic regions of Guatemala, onchocercal blindness was found in 1% to 5% of the patients [54]. Robles, an ophthalmologist from Pakheko-Luna, was the first to discover the chronic forms of eye infections of onchocercal etiology and to attract attention to this form of onchocerciasis.

In 1936, about 10,350 people were found to be suffering from the disease in Guatemala of whom 93% were from the western endemic zones and 7% from the eastern [72]. In 1938, 40% to 66% of those living on the coffee plantations in Guatemala were found to be infected.

In 1946, the number of patients in Guatemala was 20,000 [228]. Eye infections of onchocercal etiology were found in 3% of patients of whom 2% were blind [228].

In 1962 a spot-check on onchocerciasis was held in the endemic zone of Guatemala; 1,504 people were examined of whom 694 (46%) had infection of onchocercal etiology [14]. In the hyperendemic areas, of the 873 people examined, 814 were found to be infected. In the mesoendemic regions the figures were 291 and 199 respectively and in the hypoendemic regions 340 and 43 [14].

In the district of Huchuetenango many cases of onchocercal infection were reported from the coffee plantations around the towns of Kuil'ko, Sakal'temango, Demokratiya, Libertad, San Antonio, Uista, San Pedro Nekta [261]. Hyperendemic areas of onchocerciasis are known to exist in the towns of Uikhok and Providensiya [14].

In the district of Chimal'tenango, onchocerciasis is most prevalent on the coffee plantations around the towns of San Pedro, Khepokapa, Akatenango and Pochuta [261]. Surveys conducted in 1962 revealed hyperendemic areas in Panak habel', San-Rafel', Sumatan, San-Lukas and Miramar and a mesoendemic area in Santa-Rosa [14].

In the Suchitepekes district the inhabitants of the following municipalities are particularly affected by onchocerciasis: Chikakao, Patulal, San Juan Batista, San Barbara, San Antonio, and San Miguel and Panan [261]. In 1962 a hyperendemic area was reported in Moka and hypoendemic areas in El Karmen and Ofeliya [14].

In Guatemala district onchocerciasis is found in the municipality of Villya-Kanales; in the Solala district in the municipalities of San-Lukas-Toliman and Sant'yago-Atillen [261]. The number of people with onchocercal nodules in the district of Solala was 22% to 28.5% [261].

In the eastern endemic zone of Eskuintla district, people infected with onchocerciasis were found on the coffee plantations in the municipalities of Eskuintla, Santa-Lucia-Kots, Guanagaspa, Palin, San Vincente Pakaya and Siginala [261]. Those with onchocercal nodules were 13% to 28.5% in 1945 [261].

In the district of Santa Rosa patients of onchocerciasis were registered in the municipalities of Chikimulil'ya, Guasakapan and Pueblo-Nuevo-Vin'yas [261]. Between 1935 and 1962, 1,100,626 people in Guatemala were examined for onchocerciasis, of whom 235,176 had subcutaneous onchocercal nodules [9]. Microfilariae were found in 53.8% of those examined.

Treatment of patients of onchocerciasis is being provided. Surgical removal of onchocercal nodules has been practised for more than 30 years [153]. Control of the vector with insecticides has not been attempted, possibly due to the extremely difficult terrain in this region [9].

VENEZUELA: The first cases of the disease in this country were registered in 1948 in the State of Monagas [229]. The area infected with onchocerciasis is situated in the northern part of Venezuela on the eastern and western slopes of the Cordillera range (Andes), which runs parallel to the Caribbean coast; it takes in the hills and foothills between 9° and 10° latitude north. The disease is found on the coffee and sugarcane plantations. There are two endemic zones in the west and east, each covering an area of 100 to 200 square kilometers [183]. The western endemic zone is in the States of Yaracuy, Carabobo and Aragua and the surrounding regions of San Casimiro, San Sebastian, Zamora, Miranda, Cojedes and Guarico. The eastern zone covers the States of Anzoategui, Monagas and Sucre with a total population of 2.71 million.

A survey of 147 rivers in these endemic zones revealed that breeding places of black fly are present along almost their entire length [144].

During the examination in 1963 of 239,941 people living in the endemic zones onchocerciasis was found in 12,078. The highest incidence of the disease was found in the western zone in the State of Aragua (151 of every 1,000 examined) and Guarico (90 per 1,000). The lowest incidence was found in the States of Yaracuy (6.8 per 1,000) and Miranda (0.6 per 1,000). In the eastern zone, the highest incidence was found in the State of Monagas (129 per 1,000 examined). The overall incidence of onchocerciasis in Venezuela in 1963 was 50 per 1,000 examined [144]. Biopsies were positive in 40% of those examined.

A campaign against onchocerciasis initiated in 1958 is still being systematically waged. Mobile units were set up for the control of the vector. However, the results of these activities are not available at present. More than 10,000 full courses of treatment of patients with Suramin have been carried out and 4,000 patients have been partly treated.

COLOMBIA: The first case of onchocerciasis was registered in this country in 1965, when a Negro laborer became sick in the port town of Buenaventura (4° latitude north) on the Pacific coast [27]. He was found to be suffering from an eye infection of onchocercal etiology. Inhabitants of the village of San Antonio on the edge of the Cordillera range from where this patient came were examined. Out of the 312 people examined 43 additional cases were detected. However, the region was not surveyed completely because of the difficulty of reaching the villages. It was found that favorable conditions for breeding of the black fly were present in these villages and onchocerciasis might well exist there [27].

Colombia, like the other Latin American countries discussed above, has large areas of coffee plantations on the slopes of the Cordillera in the *tierra templada* zone with conditions favorable for the breeding of the flies. If carried here from neighboring Venezuela, onchocerciasis could flourish because the area is open to infection. [261].

3.6. REASONS AND DISTRIBUTION PATTERNS OF ONCHOCERCIASIS IN LATIN AMERICA

As in Africa, the area covered by the vector black fly in Latin America is considerably wider than the area of the disease.

In Latin America, onchocerciasis is found mainly in Mexico, Guatemala and Venezuela between 17°48' and 4° latitude north.

In Mexico, the areas of onchocerciasis are basically found in places at altitudes of 600 m to 1,200 m above sea level [52], in Guatemala at 300 m to 1,200 m [228] and in Venezuela at 250 m to 1,000 m [107]. Fewer cases of onchocerciasis are found above 1,200 m and above 1,800 m transmission of the disease is impossible [52, 276].

In Latin America the disease is mainly transmitted in zones at altitudes of 500 m to 1,400 m above sea level [276, 277].

As in Africa, the temperature of the air in the mountains of Latin America governs the altitudewise distribution of this disease. The altitude boundaries of onchocerciasis are the same on both continents [110].

In the countries of the South American continent, onchocerciasis is a socio-medical problem and affects the economies of the countries where it is present. It is a factor of considerable waste. The decreased working ability of the coffee plantation workers and the amount spent on medical care and preventive measures taken against blindness account for a considerable part of the budgets of these countries [9].

The fight against the vectors of onchocerciasis in Latin America presents great difficulties and the results are comparatively ineffective. The breeding places of black flies are situated in places difficult of access, being cut off by mountains and terrains covered by equatorial forest.

4. ONCHOCERCIASIS IN EUROPE

GREAT BRITAIN: By 1962, 2,000 cases of onchocerciasis had been registered. Most of them were people who had come from the endemic regions of Africa

[54]. The authors indicate that the possibility of man becoming infected through the causative organism of onchocerciasis in domestic animals [54] is not excluded in Great Britain.

A nematode of the genus onchocerca (Diesing, 1841) was identified in one case in Hungary and one case of onchocerciasis of the eyes was diagnosed in 1963 in the USSR (Crimea region) [1]. In both cases the infection is said to have been transmitted through domestic animals (horses and horned cattle).

5. ONCHOCERCIASIS IN THE NEAR EAST

In West Asia, in Aden and Yemen, where conditions are similar to those in the endemic regions of Ethiopia, 50 cases of a skin disease known as 'Sauda' clinically similar to onchocerciasis were reported between 1955 and 1956 [88, 95].

The causative organism of the disease has not been identified with certainty. Only in three of the 50 cases registered were an adult nematoda, *O. volvulus*, and a small number of microfilariae found. The vectors of the disease have not been identified either. 'Sauda' has mostly been registered in towns situated near a water source which may give some indication of the way this infection is transmitted. It has also been suggested that 'Sauda' is an independent disease [95].

In 'Sauda' the skin of the lower extremities is mainly affected. It becomes dark in color and the odoriferous and lymphatic glands swell. Of the 50 registered cases, infection of one leg was found in 32 cases and of both legs in 14. In three cases the body was infected and in one case, the arms (from wrist to shoulders) [88, 95]. Subcutaneous nodules were observed in only five cases. The pustules are usually of secondary bacterial origin [95]. Eye infections were not found in a single case. The duration of the disease is from two to five years, with sometimes fatal results [88].

In Aden and Yemen only Arabs are infected by 'Sauda', mainly males, but some females and children over 12 years suffer from the disease [88, 95].

SUMMARY

Onchocerciasis infecting man /‾causative agent: O. volvulus (Leuckart, 1893)_/ is distributed in the equatorial and sub-equatorial belts of Africa and Latin America where the causative agent of the disease finds particularly favorable conditions for its existence. Isolated cases of onchocercal infection in man have been reported from other regions. These could have been transmitted by onchocerca parasitized in domestic animals or by people coming from the endemic zones of Africa and Latin America. The development of the causative agent of onchocerciasis in man can take place only in regions having a constant temperature above 20°C. In hilly regions man can only become infected at altitudes up to 1,200-1,400 m. Above this altitude, onchocercal areas are few and above 1,800 m transmission of onchocerciasis is impossible. For the vectors of onchocerciasis, the annual rainfall and humidity of the air are limiting factors. For breeding and reproduction they need perennial fast-flowing rivers, full of rapids and waterfalls. In regions with insufficient rainfall, low humidity and often dry rivers, but situated within a zone having the right temperature range, the development of the causative organism of the disease and its transmission are distinctly seasonal and possible only in the rainy months of the year. In the dry period, transmission is suspended and the black fly vanishes without trace. There are many hypotheses as to how they withstand the dry season but so far no consensus has been reached on this question.

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APPENDIX

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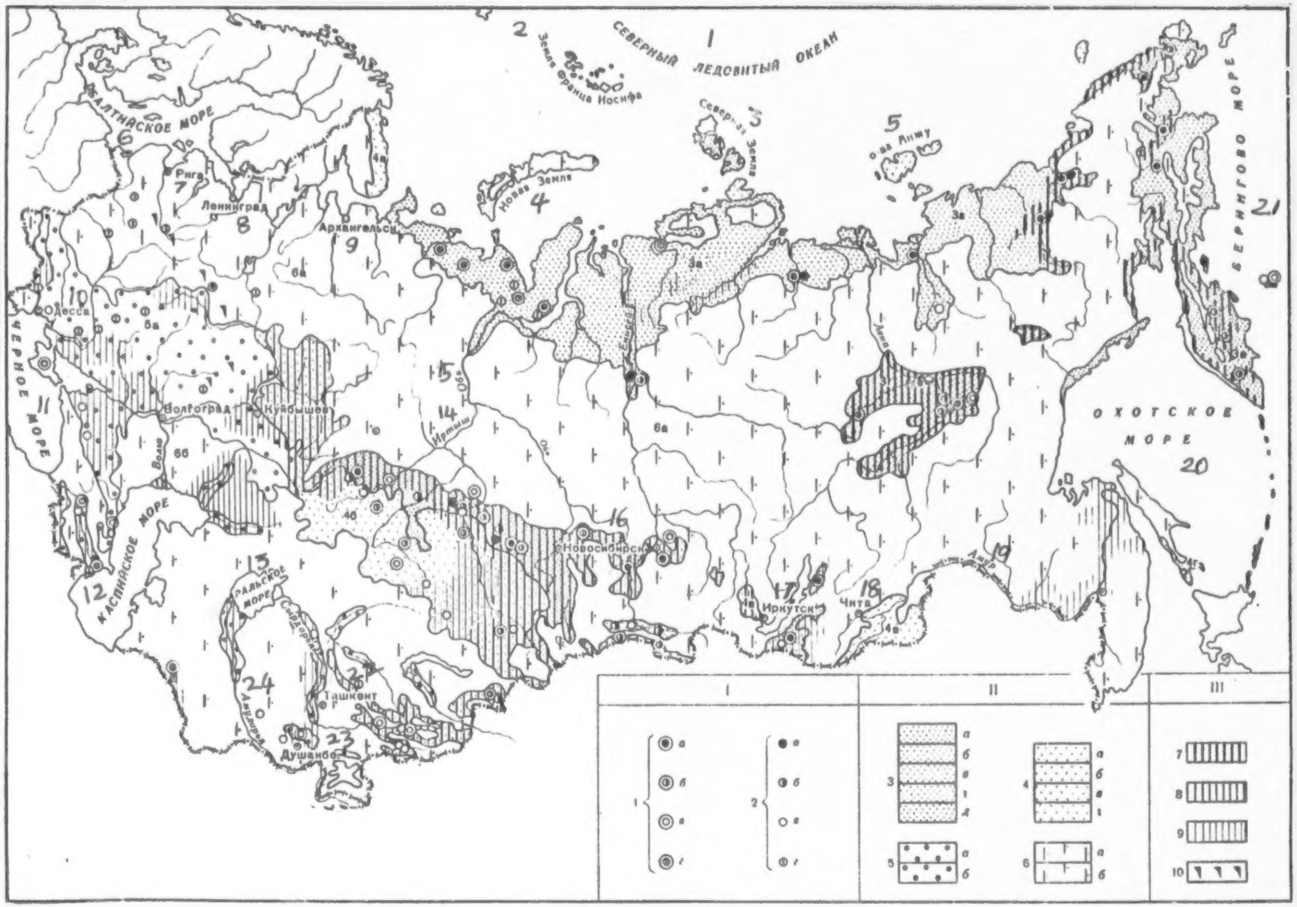
Северный Ледовитый океан
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Рига
Ленинград
Архангельск
Одесса
Черное море
Волгоград
Куйбышев
Волга
Каспийское море
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Душанбе
Иртыш
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Fig.1. Presence of alveococcus pathogen in the bionts of landscapes (infestation in % of the total number of animal-hosts investigated).

1 - Sexually mature stage in wild and domestic dog: a - more than 50%, b - from 50 to 25%, c - less than 25%, d - without statistical basis; 2 - Larval stage in rodents and domestic artiodactyls: a - more than 10%, b - from 10 to 5%, c - less than 5%, d - without statistical basis.

II. Potential danger of alveococcus infection in natural territorial complexes (the degree of danger in relation to landscape types and dominant species of epidemiologically important animals).

3 - High: a - tundra-forest tundra (polar fox, dog), b - northern taiga (fox, dog), c - subalpine Pacific Ocean area (fox, dog), d - Central taiga (dog, fox), e - forest-steppe (fox); 4 - Medium: a - tundra-forest tundra (polar,fox), b - steppe and mountain-steppe (fox, Korsak), c - mountain steppe and forest steppe (fox), d - mountain taiga)(fox); 5 - Low: a - forest steppe and steppe (fox), b - mountain steppe, semideserts and desert (fox, Korsak); 6 - Very Low: a - taiga (fox, dog), b - desert (fox, korsak).

III. Potential danger of alveococcus infection (number of patients per 100,000 rural population on five year average and autopsy data in % of total number of autopsies).

7 - 120 to 20 and 1.2 to 0.61%; 8 - 19 to 22 and 0.60 to 0.16%; 9 - Less than 2 and 0.15% and less; 10 - Presence of isolated case of infection.

Key: 1 - Arctic Ocean 2 - Franz Josef Land 3 - Severnaya Zemlya
4 - Novaya Zemlya 5 - Ayan 6 - Baltic Sea
7 - Riga 8 - Leningrad 9 - Arkhangelsk
10 - Odessa 11 - Black Sea 12 - Caspian Sea
13 - Aral Sea 14 - Irtysh 15 - Ob'
16 - Novosibirsk 17 - Irkutsk 18 - Chita 19 - Amur
20 - Okhotsk Sea 21 - Bering Sea 22 - Tashkent
23 - Dushanbe 24 - Amu Darya

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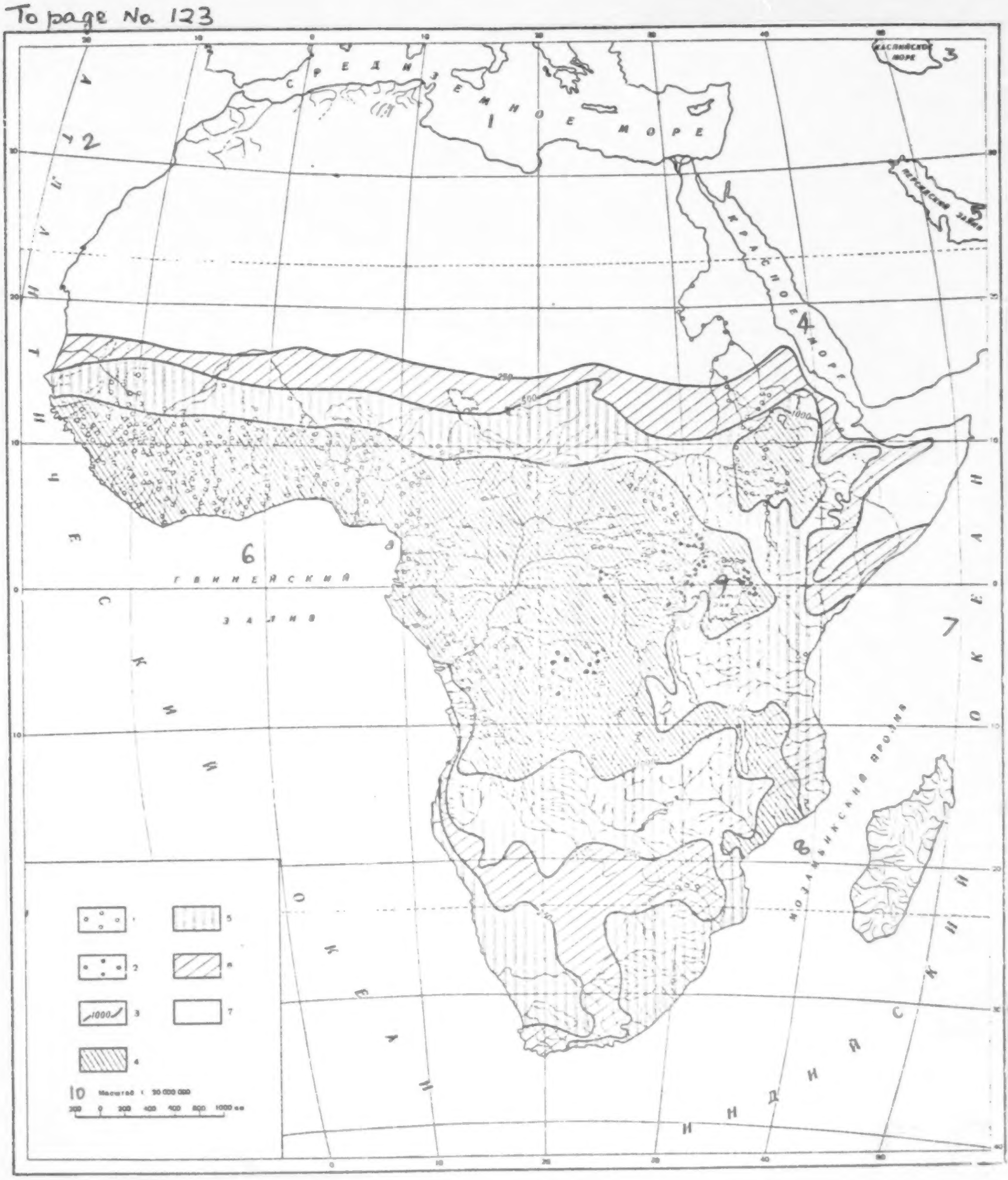
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Fig. I. Onchocerciacis carriers and the nature of hydrographic network of Africa: Locations:

I - Simulium damnosum; 2 - S. neavei; 3 - isohyets (shown on the the area of distribution of the carrier); 4 - Constant river drainage; 5 - Periodic river drainage; 6 - Episodic river drainage; 7 - Surface drainage absent.

Key: I - Mediterranean Sea 2 - Atlantic Ocean 3 - Caspian Sea ; 4 - Red Sea 5 - Persian Gulf 6 - Gulf of Guinea 7 - Indian Ocean 8 - Mozambique Strait 9 - Lake Victoria 10 - Scale

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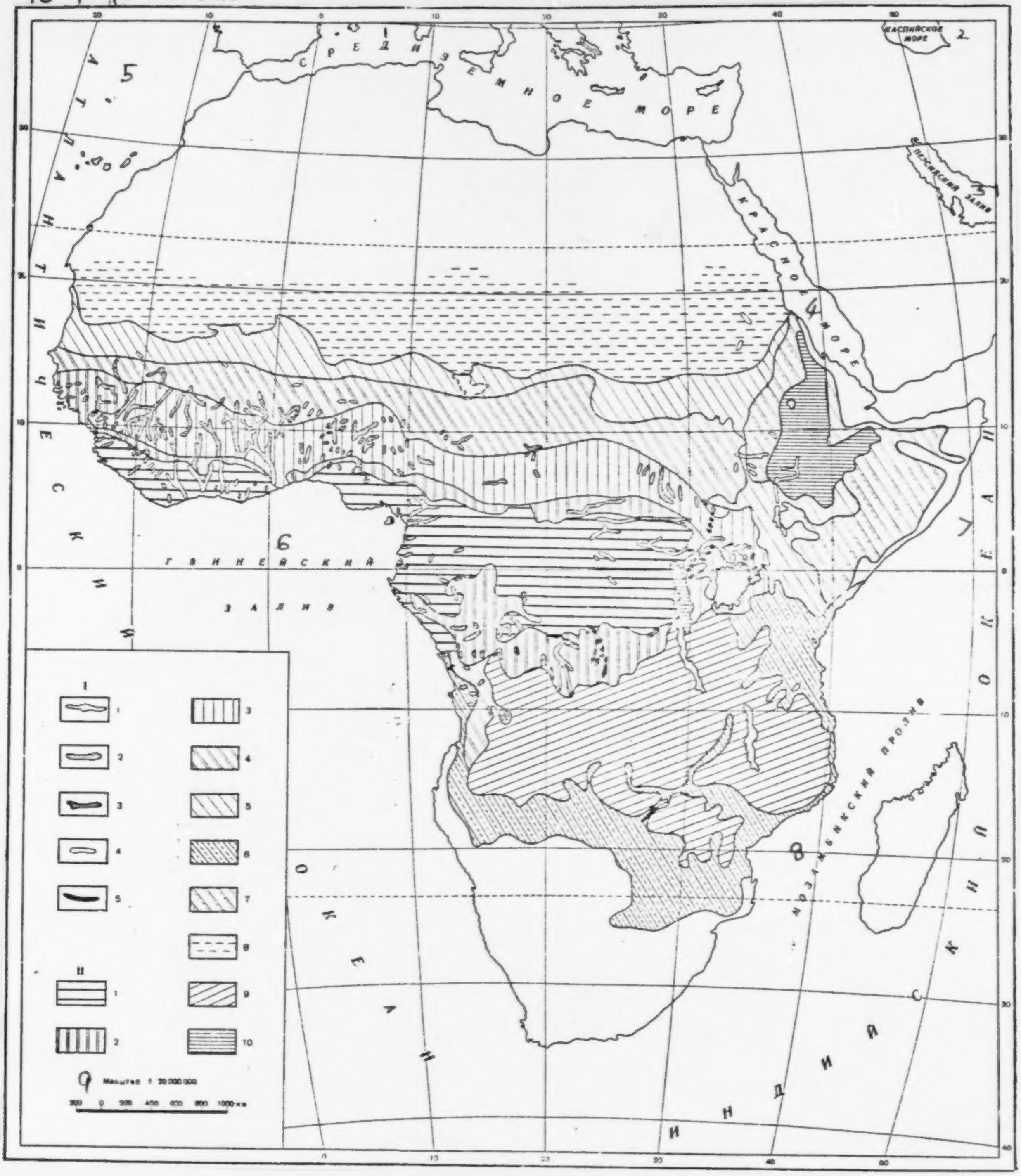
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Fig.2. Types of Onchocerciasis foci and vegetation.

I - Type of foci: 1 - type I; 2 - type II; 3 - type III; 4 - type IV; (Types I-IV - carriers of Simulium damnosum; 5 - type V (carrier of S. neavei); II - Vegetation (shown on the area of distribution of onchocerciacis foci); 1 - humid evergreen (rainy) tropical forest; 2 - park deciduous and evergreen alternately humid forests; 3 - tall-grass savanna; 4 - typical savanna; 5 - desert savanna; 6 - park savanna; 7 - thorny forests and bushes, leafless in dry part of the year; 8 - desert; 9 - sparse forest, leafless in dry part of the year; 10 - mountain park savanna.

Key: 1 - Mediterranean Sea 2 - Caspian Sea 3 - Persian Gulf
4 - Red Sea ; 5 - Atlantic Ocean 6 - Gulf of Guinea
7 - Indian Ocean 8 - Mozambique Strait 9 - Scale

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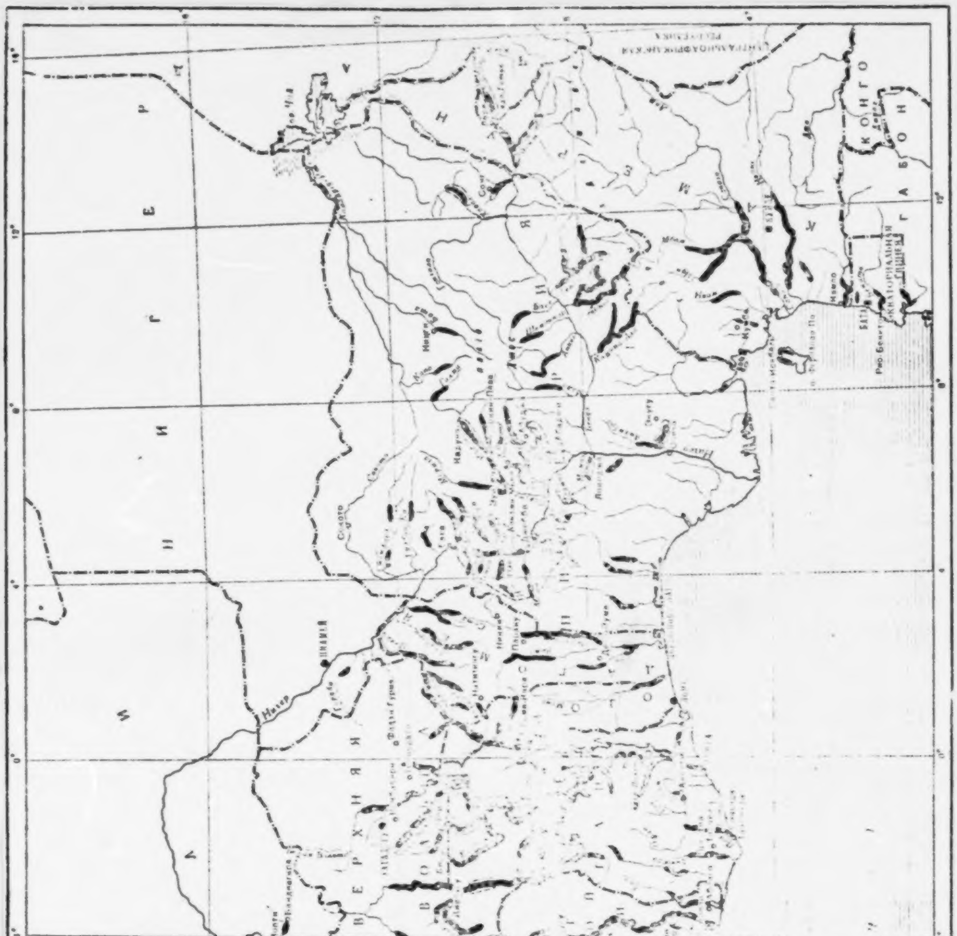
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ЦЕНТРАЛЬНОАФРИКАНСКАЯ РЕСПУБЛИКА
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Fig.3. Onchocerciasis foci in West Africa.

Dotted lines indicate foci and territories where control measures are undertaken to counter onchocerciasis carriers.

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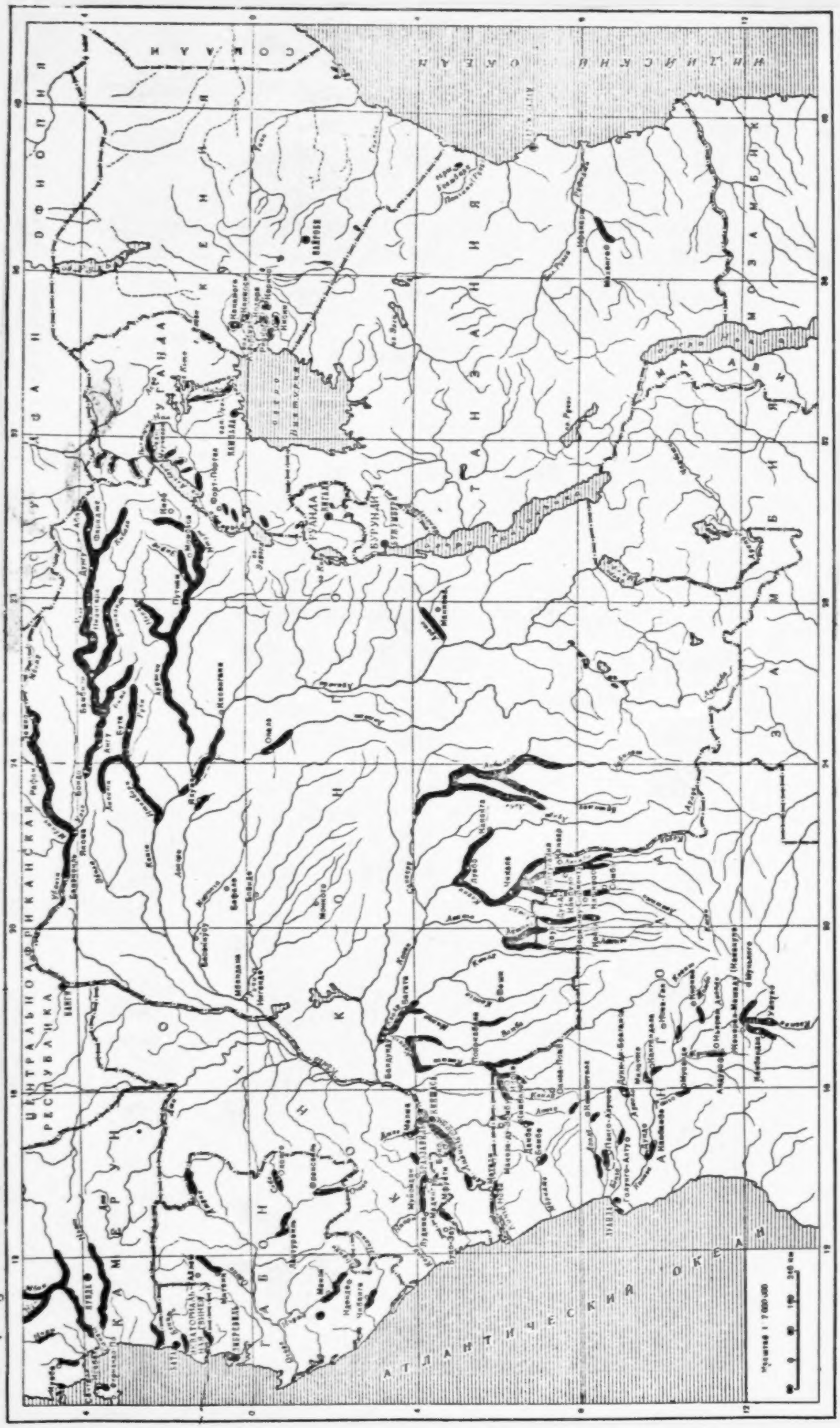
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Кампала
Банги
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Fig.4. Onchocerciasis foci in Equatorial Africa. Dotted lines show foci and territories where control measures have been undertaken to counter onchocerciasis carriers.

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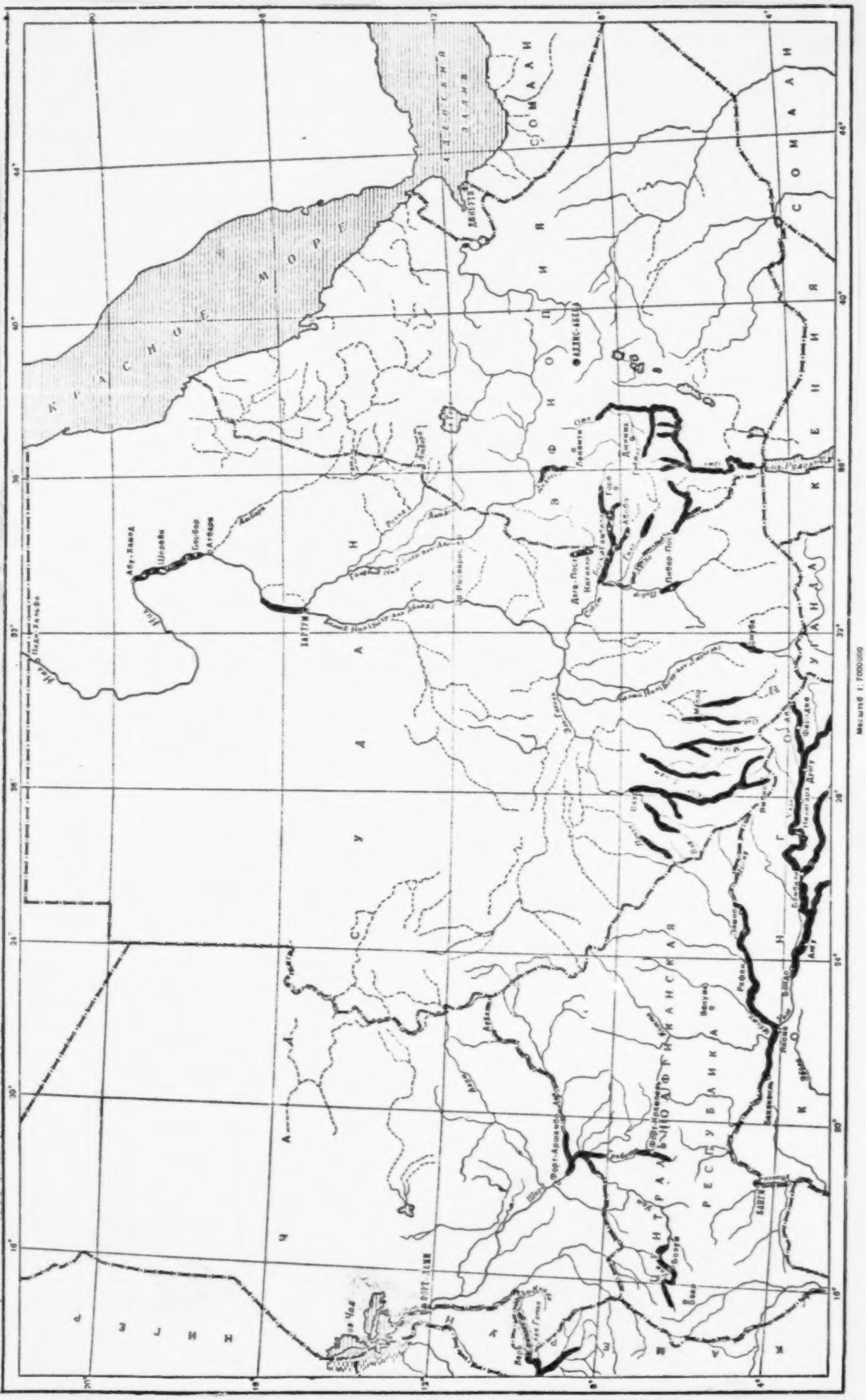
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ЦЕНТРАЛЬНОАФРИКАНСКАЯ РЕСПУБЛИКА
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КОНГО
НИГЕР
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Fig.5. Onchocerciasis foci in Chad, Central African Republic, Sudan and Ethiopia.

Dotted lines show foci in which control measures have been undertaken to counter onchocerciasis carriers.

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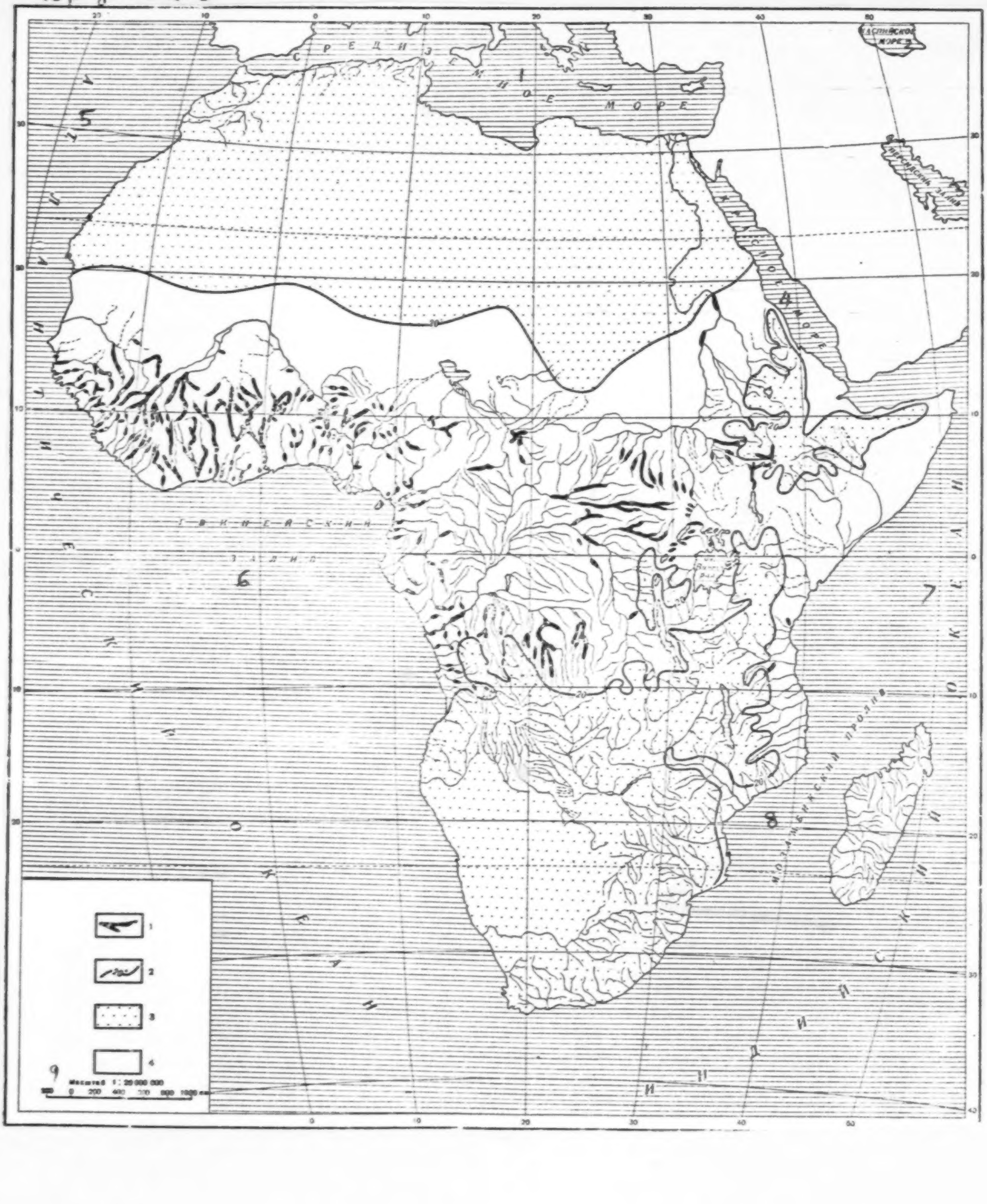
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Fig.6. Onchocerciasis foci and 20°C isotherm in the mid winter (January for northern hemisphere and July for southern hemisphere).

1 - Onchocerciasis foci; 2 - 20°C isotherm; 3 - Territory where temperature in midwinter is below 20°C; 4 - Territory where midwinter temperature is over 20°C.